Midscale Composting Manual

Alberta
ENVIRONMENT

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Mid-Scale Composting Manual

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MID-SCALE COMPOSTING MANUAL

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1. INTRODUCTION

This manual was developed by Olds College Composting Technology Centre for Alberta Environment, Action On Waste, to help municipalities, regional districts, institutions, organizations, farmers, feedlot operators and the ICI sector in Alberta to implement mid-scale composting operations. This manual includes a step-by-step guide for materials handling, feedstock preparation, monitoring and composting using a variety of methods. The manual is intended to identify the factors that affect the success of long-term programs, as well as providing technical information for managing **mid-scale** composting facilities.

ICI - Industrial, Commercial, and Institutional

This manual provides information that may be useful to a wide range of municipal groups and organizations considering mid-scale composting, including:

- municipal districts
- regional districts
- feedlots
- farms
- intensive livestock operations
- educational institutions
- ICI sectors

1.1 Why Compost?

Composting is an alternative to landfilling organic waste and can be part of every community's waste management program.

Baseline landfill volume data used by the Canadian Council of Ministers of the Environment (CCME) in 1989 estimated Canada's landfill volumes to exceed 21.2 million tonnes per year, not including agricultural, agri-food wastes, pulp and paper, commercial forestry by-products, and most biosolids from sewage treatment plants. These wastes are typically disposed of by landfilling, landfarming or incineration.

Household organic waste consists mostly of kitchen scraps and paper.

In Alberta compostable material comprises up to 70% of the waste generated by most communities (Alberta Environmental Protection: 1994). This figure includes household organic wastes, leaf and yard waste, and all paper and cardboard.

In areas which have long growing seasons and leafy trees, there is a large amount of organic material generated each year that is commonly sent to the landfill. This material has value for it's nutrients and organic matter and could be utilized through composting. Not only can these valuable nutrients be recycled, disposal issues associated with landfilling organic materials can be avoided.

When placed in a landfill organic materials decompose under anaerobic conditions. One of the by-products of anaerobic decomposition is methane, an odorous gas that contributes to the greenhouse effect. Rain and groundwater percolation through the landfill combines with decaying organic matter to produce weak acids. As these acids are washed through the landfill the groundwater may become contaminated.

Reducing organic material in landfill can help reduce the adverse effects and costs associated with methane and leachate production.

Other benefits include:

- ability to compost paper and cardboard materials that cannot reach centralized recycling services
- responsibility and accountability for dealing with waste in the community
- composting programs can be set up in the community producing the waste rather than paying for expensive transportation networks to get materials processed and marketed.

1.2 WHAT IS COMPOSTING?

Composting is a controlled biological process in which a succession of microbial populations convert organic material into a biologically stable product.

Composting can be used to produce compost, or composting can be implemented specifically as a waste treatment process. The real benefits of composting result when you do both.

Composting requires attention to:

- carbon and nitrogen ratios
- moisture content
- oxygen availability
- maintenance of favourable temperatures

Composting is typified by a microbially active thermophilic (high temperatures of 45-65° C) period while easily digestible materials are available, followed by a lower temperature curing period as more complex materials are slowly digested.

The extent of composting required for a specific material depends on the desired processing goal. Processing duration is also dependent upon materials handling and the level of process control employed. As in all biological processes, feedstock quality and preparation affects process management and final product quality.

There are two types of biological degradation processes; these are typically referred to as **aerobic** and **anaerobic**. Composting is an aerobic process. The presence of oxygen is an important factor to consider when composting.

Organic material decomposes as microorganisms break down plant material to obtain the nutrients they need to grow. Some of these microorganisms can decompose organic material only when oxygen is present. The aerobic organisms are able to decompose much more quickly than the anaerobic microorganisms. If the pile does not get turned (aerated), gets compacted, or becomes too wet, the oxygen levels go down and the anaerobic organisms take over. The compost pile begins to smell as anaerobic bacteria releases methane gas and hydrogen sulfide, a gas that smells like rotten eggs.

Table 1-1 - Recommended composting technology for various volumes of compost

Type of Composting	Volume of Waste Able to Be Composted
• static pile composting	• 50 to 1,500 tonnes per year
• aerated windrows	up to 25,000 tonnes per year
• simple channel and tunnel systems	• up to 100,000 tonnes per year
• complex channel and in-vessel systems	• up to 250,000 tonnes per year

2. COMPOST FACILITY REGULATORY REQUIREMENTS

2.1 Code of Practice For Compost Facilities

Compost Facility Classification:

An accurate assessment of the types and quantities of materials to be managed by the compost facility must be made prior to site design and preparation. This information is obviously integral for determining site design requirements, but it is also important for identifying those regulations with which the composting facility must comply. The Code of Practice for Compost Facilities under the *Waste Control Regulation* of the *Environmental Protection and Enhancement Act* (EPEA) recognizes two classes of compost facilities based on the types of waste materials managed. More specifically, the Code of Practice defines a *Class I* compost facility as that which is permitted to manage all wastes with the exception of hazardous wastes, and must fulfill specific site and operational requirements. Alternatively, a *Class II* compost facility is restricted to managing only vegetative matter and/or manure.

An approval (site-specific) under the *Activities Designation Regulation, EPEA,* is required for either a Class I or Class II compost facility that accepts more than 20,000 tonnes of waste per year for composting.

A Class I compost facility that accepts not more than 20,000 tonnes of waste per year for composting requires a registration. Detailed information requirements are outlined in the *Code of Practice for Compost Facilities*.

A class II compost facility that accepts not more than 20,000 tonnes of waste per year for composting requires a notification. Notification involves sending a letter to Alberta Environment outlining the type of facility, size, facility owner, and the location of the proposed compost facility.

The primary feedstock is usually high in nitrogen and, if exposed to rain or snow, there will be potential for leachate formation.

Compost facilities have been further defined according to the quantities of materials managed to assist with operator certification requirements effective September 2001. Three levels (*A, B, and C*) have been established for each of the two facility classes and are based on yearly tonnage capacity. Levels *A, B, and C* are used to distinguish among facilities which manage quantities of waste materials that are over 20,000 tonnes per year, between 500 and 20,000 tonnes per year, and less than 500 tonnes per year, respectively. **The mid-scale operation would fall within the 500 to 20,000 tonnes per year level and therefore be designated either a Class I B or Class II B compost facility.**

SITE DESIGN:

As mentioned, all Class I compost facilities that accept less than 20,000 tonnes of materials per year must follow the guidelines of the Code of Practice for the design, construction, and operation of the facility. Section 6 of the Code of Practice outlines the design and construction requirements.

The design and construction of a mid scale composting facility should have strategies in place to prevent air, water, and soil pollution. Measures taken to avoid environmental contamination may be simple, while others are more complex. The following are some items that are outlined in the Code of Practice and solutions on how to meet the requirements.

> *"There shall be a design plan which describes the operating capacity of the compost facility to receive feedstock, and to produce and store the compost and non-compostable materials."*

This design plan is important because groundwater contamination and air pollution could result from improper material handling. For example, if a high nitrogen feedstock is stockpiled for long periods of time in an uncovered area, there may be leachate formation and odour emissions. A comprehensive material handling plan will involve the space requirements for material storage, blending, and processing, as well the period of time that the material will stay at each stage.

As the primary feedstock accumulates, there should be a storage area that is confined and not exposed to the environment. There should also be ample supply of amendments on site to amend to the primary feedstock. Since typical amendments like straw, wood chips, and sawdust are high in carbon, they can be stored for long periods of time without producing foul odour. The carbon amendment should also be kept in a confined area so that it will not be affected by the weather. Strong winds could carry the dry particles away and pose a nuisance to neighbors. As well, highly carbonaceous materials can catch on fire if stored under very dry and hot conditions.

A blending area should be constructed close to the feedstock storage area. This will allow for more efficient movement of materials and lower equipment demands. Well blended materials can then be moved to the compost processing area which is usually a composting pad.

Hydrogen Sulphide is an odourous gas that is produced in anaerobic compost piles.

Good record keeping is invaluable for identifying sub-optimal compost conditions before they become problematic.

"There shall be a design plan which describes the structures, facilities, and equipment for control of emissions of offensive odours and contaminated liquids."

ODOUR MANAGEMENT PLAN:

Odours can be greatly reduced at composting facilities by ensuring that the materials do not become anaerobic for long periods of time. This means that high nitrogen primary feedstocks, such as manure, should not be stockpiled for any length of time. As soon as there is accumulation of sufficient amounts of materials to form a windrow or static pile the material should be blended with the appropriate amendments to optimize the composting process.

Once the material is in the processing area there should be a plan for determining the frequency and timing of turning. Regular monitoring of core temperatures, oxygen levels, and moisture contents, and good record keeping are important elements within a process management plan. A good process management plan should also be flexible and take into consideration the weather conditions and the local environment. For example, turning immature compost piles on a hot, calm day should be postponed to avoid the possibility of odour being released to linger around the facility and neighbouring community. Compost monitoring, record keeping and trouble shooting procedures are discussed in greater detail in other sections of this manual.

A special design option for odour control in aerated static pile composting operations is to use negative air-flow instead of positive air-flow. Negative flow aeration pulls air into the compost pile, making it possible to collect and filter the air through a biofilter. This set-up can greatly minimize the potential for the emission of odourous gases and fine dust particles.

RUN-ON AND RUN-OFF WATER MANAGEMENT PLAN:

A thorough understanding of the site's hydrogeology facilitates the development of a strategy for controlling run-on and run-off water. The accumulation of water from sources outside of the composting operation, by way of ditches, culverts, and general surface run-on, should be minimized for several reasons. This could result in the formation of standing water on the composting site and subsequently interfere with operations. Furthermore, these run-on waters may contain pollutants that could collect on the composting site and potentially contaminate irrigation water, composting material, feedstock and amendment materials, and the composting surface. Containment and possible treatment of run-on water may carry over as additional costs to the composting facility. However, water run-on can be easily avoided by building vegetated earthen berms around the composting site, and properly locating ditches and culverts.

"There shall be a composting pad constructed of at least 0.5 meters of clayey material having a permeability less than 5 x 10^{-8} meters / second, or an alternative material that provides equivalent protection. The composting pad should be constructed with a minimum slope of 1 percent in order that the pad does not collect water or leachate.

Run-off water can be controlled in part by grading the composting surface at a minimum of 1 % slope so that water will flow towards a constructed lagoon or containment basin, rather than pooling on the site. In some facilities, underground leachate tanks are constructed to collect and store run-off water. It is recommended that lagoon water and stored leachate be tested regularly to monitor for pollutants and their concentrations. If the collected run-off water is not problematic, then it may be released or used for moisture management of compost piles. If collected run-off fails to meet water quality standards, then treatment will be required.

There are a variety of technologies that can be integrated into the site design for insitu treatment of collected run-off water and leachate. Many of these technologies successfully employ natural processes rather than chemical or physical manipulation. These eco-technologies include the use of constructed (i.e. not natural) wetlands, grassy swales, flooded meadows, and trees, either individually or in combination, to treat run-off and lagoon water. Plants used in these fabricated systems cleanse run-off water by absorbing and incorporating excess nutrients, especially nitrates and phosphates, into their own tissue. Moreover, plant roots, stems, and leaves provide additional surface area upon which bacteria, fungi, and, in some cases, algae can flourish. These communities not only remove dissolved nutrients, but also feed on carbon compounds that are suspended as solids or dissolved in the aqueous solution. Plants and associated microorganisms in these systems can also help reduce concentrations of heavy metals.

However, these elements become stored in living biomass and can accumulate throughout the food chain. Therefore, other treatment methods are necessary if run-off or leachate waters are found to contain high levels of heavy metals or other non-transformable pollutants.

Mid-scale Class 1 Composting - composting facilities that receive up to 20,000 tonnes of feedstock per year including wastes other than vegetative matter and manure, such as mixed municipal solid waste and sewage sludge.

Unchecked accumulation of run-on water may burden the composting site's lagoon or containment basin beyond its designed capacity.

Non transformable pollutants remain harmful even when passed from one species to the next.

GROUNDWATER MANAGEMENT PLAN:

The construction of an effective composting pad is an important aspect of any mid size facility that is using static pile or turned windrow composting systems. The compost pad should be durable and impermeable to leachate. Materials are processed on the composting pad and this involves the movement of heavy machinery. Even the use of lighter equipment, such as tractors and small loaders, may result in ruts in the pad if it is constructed with materials that can not endure the activity. During periods of heavy rain the usage of heavy equipment may have to be suspended.

Figure 2-1: Compacted clay pad with ruts and leachate accumulation arising from the use of equipment during heavy rainfall.

Clay pads are most common and economical for mid scale facilities in which composting and processing require a large work surface. However, the type of clay used must meet the permeability requirements set by the Code of Practice for Compost Facilities. This is to ensure protection of the groundwater against contamination from compost leachate which may contain pollutants. Concrete and asphalt composting pads provide excellent protection for groundwater contamination, can endure heavy equipment and permit site activity under wet conditions. The major drawback of using these types of surfacing materials is that they can be expensive and will require periodic repair or replacement.

In order to avoid leachate accumulation on the composting pad and to improve the drainage of run-off to the lagoon the composting pad must be sloped towards the leachate collection system. As discussed previously, a slope of 1% on the composting area is usually sufficient for proper drainage.

GROUNDWATER MONITORING AND QUALITY:

The groundwater monitoring system should be installed beneath the composting pad in the form of groundwater monitoring wells or lysimeters (Figure 2-2). The number of wells required to monitor the site will depend, in part, on the type of surface material used, the size of the composting pad, and the types of materials to be composted. These wells must be kept in good repair and locked when not being used for sampling wells.

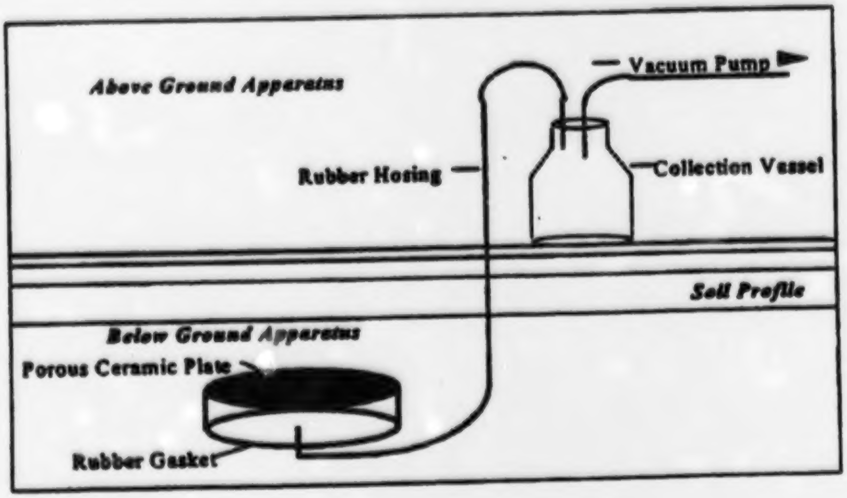


Figure 2-2: A schematic diagram of a typical soil lysimeter for groundwater sampling. Soil water is pulled by vacuum force through a porous ceramic plate that has been placed in the soil profile with minimal disturbance. Soil water is collected in bottles located above ground and replaced regularly, as per sampling period.

"Persons responsible for the compost facility may be required to construct and maintain a groundwater monitoring system where the compost facility is not enclosed within a structure or vessel. This is required when:

a) the volume of feedstock exceeds 5,000 tonnes per year
b) the compost facility is located on a natural geological material with a hydraulic conductivity that is greater than 5×10^{-7} meters per second and within 5 meters vertically of an unconfined aquifer
c) the base of the composting pad is less than 1 meter above the seasonally high water table"

Groundwater sampling should be carried at a minimum frequency of once per year. Water samples should be analyzed for at least three specific parameters, namely: pH, chloride concentration, and nitrate concentration. Recorded levels should be compared to the performance standards set by the Code of Practice for Compost Facilities, Section 8(3), and are tabulated below (Table 2-1).

Table 2-1: Groundwater quality standards set by the Code of Practice.

Parameter	*Performance Standard*
Chloride (Cl^-)	**< 250 mg/L**
Nitrate (NO_3^-)	**< 10 mg/L**
pH	**6.5 to 8.5**

The number of sampling wells, the sampling frequency, and the number and types of water testing parameters may be specified during site planning or altered subsequently by the Director of Alberta Environment (see Code of Practice for Compost Facilities, section 8(4)). Requirements regarding the groundwater monitoring plan of a compost facility will be based on:

1. *the character of the feedstock received;*
2. *changes observed in groundwater quality; and*
3. *other evidence that suggests an impact on groundwater quality.*

If groundwater quality standards are not met, then the facility operator must notify the Director and implement a groundwater remediation plan.

In-Vessel Systems:

Site Design Considerations

Although not specifically addressed by the Code of Practice, in-vessel composting systems, which include bins, agitated beds, silos, and rotating drums, can also be used in mid-scale composting operations. These composting systems offer special design features that confine the composting process within a building, container or vessel, and optimize composting activity using mechanical manipulation and/or forced aeration. Some specifications outlined above, such as those pertaining to surface material permeability and site slope, may not be applicable in all of these systems. Nevertheless, reasons for these specifications should be considered in the selection and construction plans of any mid-scale composting operation.

Odour Management Plan

By enclosing the composting process, in-vessel systems should facilitate odour management. Systems using forced aeration can collect and filter air, thus helps to greatly minimize the potential emission of odourous or pollutant gases, and fine particles.

Run-on, Run-off, and Groundwater Management Plan

By containing the composting process, in-vessel systems should eliminate run-on water concerns. Furthermore, they greatly facilitate the control of run-off water and leachate by sheltering the composting materials from precipitation. In addition to greater moisture control, in-vessel systems are typically designed to collect and recycle liquids produced within the system. Therefore, in a well-planned in-vessel system, measures for surface and groundwater contamination prevention should be inherently found in the initial design. Water quality testing should still be done periodically on collected leachate even if it is destined to be recycled within the system. If the leachate contains contaminants, then recycling it may lead to a higher concentration of contaminants in the final product or the potential contamination of the next product batch.

COMPOST QUALITY:

The Code of Practice for Compost Facilities has outlined the pathogen kill requirements for finished compost. According to the Code of Practice, if the feedstock is known to contain human pathogens then the following requirements must be met:

a) fecal coliforms shall be less than 1000 MPN per gram of total solids calculated on a dry weight basis

b) *Salmonella sp.* shall be less than 3 MPN per 4 grams of total solids calculated on a dry weight basis, where the Most Probable Number method of analysis is used, or otherwise non-detectable by other generally accepted methods of analysis.

A representative sample of finished compost should be collected from each batch of compost and analyzed for fecal coliform and Salmonella sp. This can be done by sending the compost sample to any microbiology laboratory. This must be performed before the compost is sold or used. If the levels of pathogens do not meet these requirements the compost should be processed further. Addition of fresh feedstock may be necessary to regenerate thermophilic temperatures to kill the pathogens. If further processing is not feasible then the compost should be pasteurized to kill the pathogens.

If the feedstock is not known to contain human pathogens then the following requirements is sufficient for pathogen kill:

a) in an in vessel or aerated static pile system, the compost shall be maintained at operating conditions of 55°C or greater for 3 days.

b) in a windrow system, the compost shall attain an internal temperature of 55°C or greater for at least 15 days, and during the stage, the windrow shall be turned at least 5 times.

In order to meet these requirements the operator must monitor temperature of the windrows diligently to prove that this requirement has been met. Furthermore, the frequency of windrow turning should be monitored. For windrow composting, the temperature should be monitored at the core of the windrow to satisfy this requirement. Effective process management is essential in order to ensure the windrows attain high enough temperatures for pathogen kill.

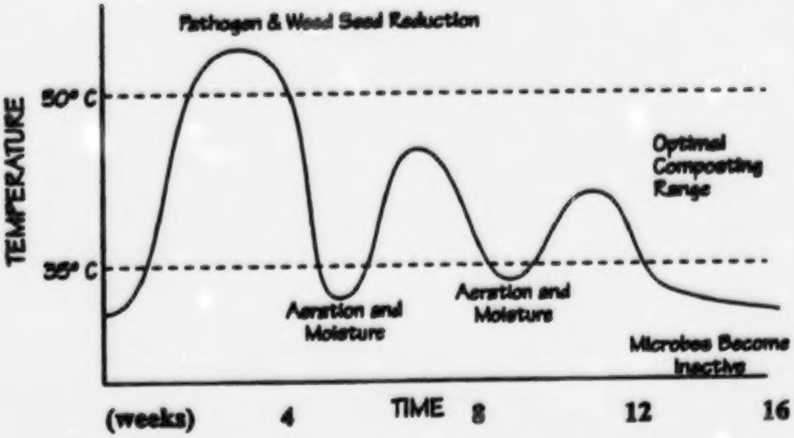


Figure 2-3: Typical composting temperature profile. The minimum length of time to reach pathogen kill is to obtain 55°C for 2 weeks in windrow composting.

2.2 COMPOST QUALITY - CCME

Although pathogen kill requirements are specified in the operating requirements of the Alberta Code of Practice for Compost Facilities, the standards outlined in the *Compost Quality Guidelines* set by the Canadian Council of Ministers of the Environment (CCME) must also be met for compost quality.

In brief, the CCME *Compost Quality Guidelines* provide a system for classifying compost with regards to product end-use based on specific trace element concentration limits, particularly those elements that could cause adverse effects on human health and/or the environment. The two classes of compost use described in this CCME document are for unrestricted use (Category A) and for restricted use (Category B). Use of Category B compost is restricted such that the cumulative concentration (compost and soil) of each specified trace element does not exceed the Maximum Cumulative Additions to Soil standards, as defined by the Agriculture and Agri-Food Canada's Fertilizer Act (Trade Memorandum, T-4-93, January 2, 1991), and meets provincial or territory requirements. In the future, concentration limits of other trace elements such as aluminum, boron, iron and manganese may be regulated to meet regional and national concerns as they are identified.

Table 2-2. Maximum allowable limits of CCME regulated trace elements in Category A and Category B Compost (from CCME Guidelines)

	Category A	Category B	
Regulated Trace Element	Concentration within Product (mg/kg)	Concentration within Product (mg/kg)	Cumulative Concentration within Soil-Product mix (kg/ha)
Arsenic	13	75	15
Cadmium	3	20	4
Cobalt	34	150	30
Chromium	210	1060*	210*
Copper	100	757*	150*
Mercury	0.8	5	1
Molybdenum	5	20	4
Nickel	62	180	36
Lead	150	500	100
Selenium	2	14	2.8
Zinc	500	1850	370

*Limits for Cr and Cu are not specified by the Fertilizer Act but have been calculated as was done for the nine other trace elements.

The CCME Guidelines also suggest various test criteria and associated limits that can be used to assess compost maturity, since an immature product could harm plants if used in sizable quantities. These tests include specific carbon to nitrogen ratio limit, a maximum limit of oxygen uptake, Cress Bioassay for phytotoxicity assessment, and specific minimum curing periods and conditions.

[1]Concentration standards under the Agriculture and Agri-Food Canada's Fertilizer Act (Trade Memorandum, T-4-93, January 2, 1991)

MATURITY:

The hallmark of a mature compost is that it has undergone microbial degradation of practically all of the biodegradable organic constituents to form humus, a stable complex colloidal nitrogenous lignin compound beneficial to plant growth. Furthermore, nutrient conservation, pathogen destruction and bulk reduction must also have occurred for the compost to be designated as mature.

Compost that has not fully cured is considered immature.

An immature compost with undegraded organic matter still present, will undergo further active humification in the treated host soil, depleting plant roots in the rhizosphere of oxygen and nitrogen. It also has a high concentration of the intermediate products of biodegradation (ammonia, phenols and aliphatic acids) which are phytotoxic to plants.

Because compost is such a variable, complex and heterogeneous material, produced from a wide variety of organic substrates, no single test for compost maturity is reliable and sufficient by itself, so the use of several tests are required.

By products produced by the microbial degradation of organic matter can be harmful to plants.

Compost is mature when two of the four tests are met.

1. Two of the following three tests shall be met:
   a. C:N< 25:1
   b. Oxygen uptake < 150mg O_2/kg organic matter (volatile solids)/hour.
   c. The germination of cress (*Lepidium sativum*) and /or radish (*Raphanus sativus*) seeds in the compost:
      * Test seed germination shall be > 90% of control seed germination.
      * Test growth rate shall be > 50% of control growth rate.

2. The compost must be cured a minimum of 21 days and not reheat to greater than 20^{o}C above ambient temperature after being aerated and formed into a test pile no less then 1.8m in diameter,1.2m high and having a percent moisture of 35 - 50%. Temperature shall be measured at 60cm depth 3 days after pile formation.

3. The compost must be cured a minimum of 21 days with the reduction of organic matter to be greater than 60% by mass.

4. The compost must be aerobically cured for a minimum of 6 months if no other maturity test is made. This curing stage begins when the pathogen reduction process is complete and the material no longer reheats to thermophilic temperatures.

THE CRESS GERMINATION TEST:

This is a sensitive test as plants are most susceptible to the phytotoxins in immature compost at germination and seeds are particularly prone to the intermediates of biodegradation (phenols and aliphatic acids).

Cress is an ideal test candidate as it germinates quickly (24 - 48 hours) and is very sensitive to salinity and pH of the growth medium. Also, the small seeds are more susceptible to the phytotoxins in immature compost.

A composite sample of the finished compost is collected from the windrow when the pile no longer reheats.

A compost mixture should be prepared for the cress seed germination and growth test. Since it is not specified in the CCME Guideline for a test percentage, amendment rate of not more than 40% is recommended. This is based on the common assumption that compost should be used as a soil amendment.

Cress seeds grown in the test mixture should be compared to seeds grown in a control mixture of potting soil.

A positive cress test is determined by the germination and growth rate of the cress seeds grown in the compost mixture compared to a control. The growth rate must be greater or equal to 50% and the germination cannot be less than 90% of the control.

FOREIGN MATTER:

This refers to non-biodegradables materials in composts such as:

- glass
- metal
- rocks
- rubber
- styrofoam
- plastic

Compost should be virtually free of foreign matter which may cause injury to humans, animals and plants or damage to machinery during or resulting from its intended use. Generally, the limit should not be more than 1% of the compost by dry mass of combined foreign matter. This can be measured by passing a known mass of finished compost through a series of screens, picking the extraneous matter from the screens and weighing their combined mass.

sharps < 3mm, other foreign matter < 25mm

Furthermore, compost should contain no sharp foreign matter measuring more than 3mm in any dimension and no foreign matter greater than 25mm in any dimension.

These extraneous items are removed with appropriate screening devices prior to composting once the compost is cured and used in the prescribed manner. The choice of "clean" starting material can avoid the existence of these undesirable contaminants. Source separation of non-biodegradable materials for municipal solid waste is an example of preventing foreign matter from entering the compost.

MEASURING THE AMOUNT OF CONTAMINANTS

This test is to determine the amount of contaminants that may be present in a compost sample.

To measure the amount of contaminants do the following:

1. Take a sample of compost
2. Weigh the sample of compost
3. Screen the compost
4. Visually inspect the material left on the screen
5 Separate the contaminants
6. Weigh the contaminants
7. Calculate the percentage of contaminants by:
   $$\%\ of\ contaminants = \frac{weight\ of\ contaminants\ (\#6)}{weight\ of\ sample} \times 100$$
8. Record the percentage if the % of contaminants is greater than 30, then additional education needs to be addressed.

PATHOGENS IN COMPOST:

As pathogenic organisms may be present in the compost feedstock, the finished compost may also contain pathogenic organisms and be capable of posing a health risk to humans. To adequately reduce this health risk, the compost shall conform to the criteria outlined below depending on the source of the feedstock.

a) When a compost does not contain feedstock that is known to contain human pathogens, **one** of the following two criteria shall be met:

   1. The compost shall undergo the following treatment or other adequate process recognized as equivalent by the relative province or territory:

      Using the in-vessel composting method: The material shall be maintained at a temperature of 55oC or greater for 3 days.

      Using the windrow composting method: The material shall attain a temperature of 55oC or greater for at least 15 days. During this high temperature period the windrow shall be turned at least 5 times.

   2. The concentration of indicator organisms for human fecal contamination shall meet **both** the following:

      Fecal coliforms: < 1000 MPN/g of total solids calculated on a dry mass basis.

      Salmonella sp.: < 3 MPN/4g of total solids calculated on a dry mass basis.

b) When compost does contain a feedstock putatively high in human pathogens, **both of** the following **two** criteria shall be met:

   1. Undergo a treatment as described in a)1. or other process recognized as equivalent by the relative province or territory.

   2. The concentration of indicator organisms for human fecal contamination shall meet **one** of the following:

      Fecal coliforms: < 1000 MPN/g of total solids calculated on a dry mass basis.

      Salmonella sp.: < 3 MPN/4g of total solids calculated on a dry mass basis.

ORGANIC CONTAMINANTS IN COMPOST:

Organic chemicals (PCB, PAH, Furan, Dioxin, Organophosphate and pesticides) enter waste streams from a variety of industrial and domestic sources. While many degrade or volatilize during waste collection, treatment (including composting) and storage, some of these organic chemicals persist.

The provinces/territories and federal government can establish specific requirements for organic contaminants based on the feedstock source (e.g., industrial sludges.)

The risk of overt contamination by organic chemicals is negligible in the majority of composts e.g., leaf and yard waste composts.

3. MATERIALS HANDLING

3.1 PRIMARY FEEDSTOCK PROCUREMENT

Feedstock - the material of which a compost pile or windrow is composed of is referred to as the feedstock.

The primary feedstock is typically high in nitrogen and easily biodegradable

Municipal Solid Waste includes materials such as grass clippings, papers, cardboards and food scraps.

The primary feedstock is almost always a waste that is produced, and that has the potential to be something more valuable than it currently is. The following are examples of five industries and the primary feedstocks they produce:

1. Food processing residuals: fruits, vegetables, grain, tallow and various sludges.
2. Manure and agricultural wastes: cattle, poultry, swine and dairy manure and paunch.
3. Forestry and forestry by-products: wood chips, pulp sludge, bark, and sawdust.
4. Municipal wastewater treatment: sewage sludge.
5. Cities and municipalities: leaf and yard waste, and municipal solid waste.

Procurement of the primary feedstock may be as simple as moving it from the collection pad to the composting site pad. It can also be as difficult as trying to coordinate the emptying of large commercial bins, and transportation of the waste to a centralized composting area.

Whatever the method chosen to obtain the primary feedstock, it must be cost effective and efficient for the intended operation. For example, one would not use a tractor with a one cubic meter bucket to move five kilometers to the composting site. For moving large volumes of material, it may be far more effective to use a large truck and a loader to transport the primary feedstock over long distances. For shorter distances it may be equally as effective to use a smaller loader.

Optimally, the primary feedstock should be free from contaminants, and any unwanted debris. Debris such as rocks pose a threat to worker's safety, especially when windrows are manipulated by a windrow turner. Contaminants such as rocks or large pieces of wood can become dangerous flying projectiles when a windrow turner is used.

Since the primary feedstock is usually high in nitrogen and easily putrescible, an appropriate storage area should be prepared.

3.2 AMENDMENT PROCUREMENT

A compost amendment is any component of the composting mixture, that aids in the composting process. A composting amendment may be used to increase the nitrogen content, such as manure, or high nitrogen fertilizer. Amendments can be used to increase carbon content or also increase the porosity of the compost mixture, such as wood chips.

Ensure that nails and other inorganic materials do not contaminate the windrows during the preparation stage. Large wooden pieces that may bypass the shredder should be carefully removed.

The types of amendments needed will vary according to the feedstock. Some common carbon amendments are:

- wood chips
- paper
- leaves
- straw
- corn stalks
- sawdust

Some common nitrogen amendments are:

- manure
- clover
- fresh grass clippings
- spoiled alfalfa pellets

Many of these are readily available depending upon your location and many of these may be acquired at little or no cost.

3.3 STORAGE FACILITIES

Usually the amendments are stockpiled on the compost pad in preparation for the arrival of the primary feedstock. Carbon sources such as wood chips can be stockpiled on open ground with little fear of groundwater contamination, or becoming an unsightly mess. Other amendments such as paper, leaves, grass, and loose straw can be strewn around by the wind and become intermingled resulting in an unsightly mess. Therefore, it is important both from an aesthetic point of view and quality control point of view to contain these materials.

Storage facilities can be elaborate, such as a covered cement bunker with leachate channels that drain to a collection pond. Storage facilities can also be as simple as an open-air dirt pad. The type of storage facility used for the amendments will depend greatly on the type of feedstock being used, and the overall volume of material. Whatever type of storage facility is used, the storage facilities must be appropriate for the material being handled, and caution must be exercised to avoid mixing of the feedstock and amendments while in the storage areas. It is also important to keep feedstock from becoming mixed with the finished compost, as this will affect the quality of the final product.

3.4 GRINDING AND SCREENING

PARTICLE SIZE:

Particle size affects the composting process by influencing aeration and size and continuity of the interstitial air spaces. Adjustment to the required particle size is accomplished by grinding the material before pile formation.

As composting proceeds, particle size is reduced as the nutrients are consumed. Therefore it is prudent not to start with too small a particle size.

Too large a particle size will cause large air pockets and the pile might not heat up. Too small, and there is the risk of anaerobism due to inadequate aeration and clogging the small air spaces with water.

A compromise as to particle size is necessary as smaller particles have a larger surface area for microbial attack and complete degradation will take a shorter time. However, this also increases oxygen demand which could cause anaerobism and more turning operations.

Particle size and distribution can be measured with a set of graduated sieves on a vibrating platform. The proportion of each size category can then be calculated once a known mass of sample has been passed through the sieves.

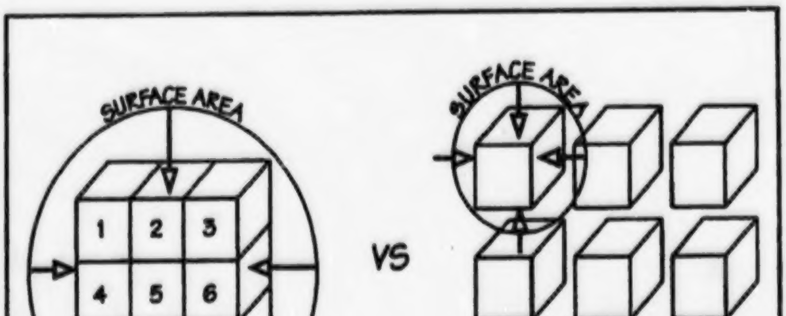


Figure 3-1: Surface area to volume ratio is important for composting. The greater the amount of surface area for microbial attack, the faster the material will break down.

GRINDING:

Choosing the optimum particle size will depend on the feedstock, and the amendments used. By pre-grinding materials such as paper, tree branches, and cardboard to the right size, composting will be more efficient, and the material will require less manipulation.

There are many types of grinders and shredders available. Some examples include hammer mills, tub grinders, rotary drum grinders, and rotary shear shredders.

Hammer mills use free-swinging hammers that are attached to a rotating drum. Material that is introduced into a hammer mill is broken down by the hammers until it is reduced enough to pass through the discharge openings. Because of their nature, hammer mills can be quite large. These units more often than not are stationary, thereby requiring additional material's handling.

Figure 3-2 Tub Grinder

Tub grinders use a rotating tub to move material into either a hammer mill, or a shear shredder. The material is then broken down until it can pass through a discharge screen, or grating. Once through the grating the material is moved up an incline conveyor and is discharged onto a pile. Tub grinders may be powered in one of three ways. They may require a tractor to power them, by using the power take off. They may have a gas or diesel motor attached directly to the tub grinder. They may also be powered by a large electric motor.

Tub grinders are very mobile and can be positioned very close to the composting site. This reduces the amount of material handling required. Rotary drum grinders, such as forage grinders, may also be used. These units use a conveyor to move material into a rotating drum that has teeth and/or knives mounted to the drum. That material is reduced in size by either a cutting or shearing action. The material is then discharged on an incline conveyor into a pile.

A rotating shear shredder uses two counter rotating shafts that have discs welded onto the shafts. As the discs rotate, any material that is introduced is shredded due to the tight spacing between counter rotating discs.

SCREENING:

Biodegradable rejects can be stored and added to active compost, whereas, all non-biodegradable material should be disposed of in an appropriate manner.

Contaminants should be removed from the feedstock using various sizes and dimensions of screens because contaminants may:

- pose danger at the composting facility
- cause equipment breakdowns and maintenance problems
- blow around at the facility making it look unsightly
- decrease the value of the finished product

Contaminants typically include:

- plastic bags
- plastic containers
- glass
- metal
- batteries
- rocks

Screening finished compost separates large particles such as rocks, plastic, and other unwanted materials. When screening, it is important to take into consideration the screen openings. For compost, the screen openings should be in the range of ¼" to ½". The moisture content of the material being screened should be less than 40%. Material that has a moisture content higher than this amount will cause the screen openings to plug. When the screen openings become plugged the screening efficiency is lowered, and particles of a smaller size may end up in the reject pile.

Typical screeners include trommel screeners and flat vibrating face screeners. Trommel screeners employ a rotating screen that allows particles smaller than the screen openings to fall onto a conveyor to be stockpiled. Materials that are larger than the screen openings are moved off of the screen due to the rotating motion, onto a conveyor, which moves the rejected material to a separate pile.

A flat vibrating face screener separates material using an oscillating motion to move undersized material through the screen, and to move oversized material off the screen.

3.5 Recipe Formulation and Blending

The amount of primary feedstock and amendment that should be blended together depends on the nitrogen and carbon content of the material. The amount of carbon and nitrogen in composts need to be carefully balanced to ensure optimal microbial activity. The target C:N ratio for composting is within the range of 30-40:1. Therefore, a C:N ratio of 30:1 means that there is 30 parts of carbon for every part of nitrogen. In order to reach this balance of carbon to nitrogen, high nitrogen feedstocks require high carbon amendments.

Some typical C:N ranges for feedstocks are:

<u>**Material**</u>	<u>**C:N ratio**</u> (average)
Grass clippings	17:1
Leaves	54:1
Wood chips (softwood)	641:1
Hay (legume)	16:1
Straw (wheat)	127:1
Manure (cattle)	19:1

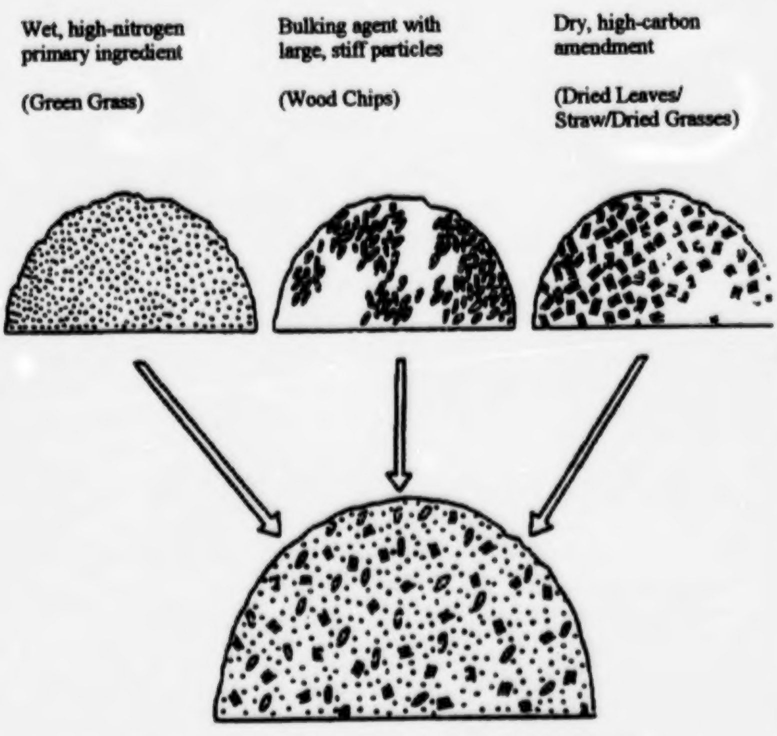


Figure 3-3 Schematic diagram of blending composting feedstocks

The frequency of mixing and turning will be dependent mainly on temperature and moisture content.

It is very important to maintain a schedule of turning.

During fly season, the windrows should be turned once a week despite temperatures. Weekly turnings break the fly reproductive cycle.

The blending of the primary feedstock and the amendments may be achieved in several different ways. All of them should have the same end objective, which is to complete homogenization of the primary feedstock and the amendments.

Homogenization of the materials can easily be achieved by using a windrow turner. The formation of a windrow should follow these parameters when possible. The windrow should be constructed in layers, beginning with a layer of amendment, then a thin layer of primary feedstock. The formation of the whole windrow should proceed in this fashion until the maximum windrow height has been achieved (this will be determined by the size of the turner). At this time any water that needs to be added to increase the moisture content of the material, should be added prior to mixing. After the windrow has been formed, it should be turned a minimum of two times with the windrow turner to ensure a good degree of homogenization.

If the windrow is to be formed using a bucket loader or a skidsteer, the parameters involved in the initial mixing are different. In this case, formation of a large thin bed of amendment should by laid out, this should then be covered with a thin layer of the primary feedstock.

Through a process of folding using the bucket of the loader, and back dragging the material, the material will attain a good degree of mixing. The degree of mixing will also depend greatly on the operator, and the operator's experience. Once the mixing of the material has been completed, it should be placed in an appropriate area of the compost yard in either a pile or a windrow.

The formation and mixing of windrows may also be accomplished by using manure spreaders. In this instance, the feedstock and the amendments should be loaded into the manure spreader in the appropriate proportion. The manure spreader should then be taken to the site where the windrow is to be formed. The spreader should be started and pulled forward only when the appropriate windrow height has been achieved.

Truck mounted manure spreaders have the advantage of building larger windrows, as they are typically higher than tractor drawn manure spreaders. It is also important when using a manure spreader to make sure that the materials being used contain no large objects or rocks that may damage the equipment, or pose a threat to the personnel operating the equipment.

3.6 VOLUME TRACKING

During the course of the composting process, the volume of the composting material will decrease. It is necessary to track volume changes in order to assess the amount of space that will be needed on the composting pad or that can be made available by maximizing the size of the windrows on a continuing basis. Volume reduction is also a good indication for composting performance.

In order to calculate the volume of a windrow, formed by a self-propelled windrow turner, it will be necessary to take the following measurements. Measure the width, the height, the length at the top of the pile, and the length at the bottom of the pile.

The formula for calculating windrow volume is:

$$\text{Volume (m3)} = 1/2(\,(L1 + L2\,/\,2\,) \times H1 \times W1)$$

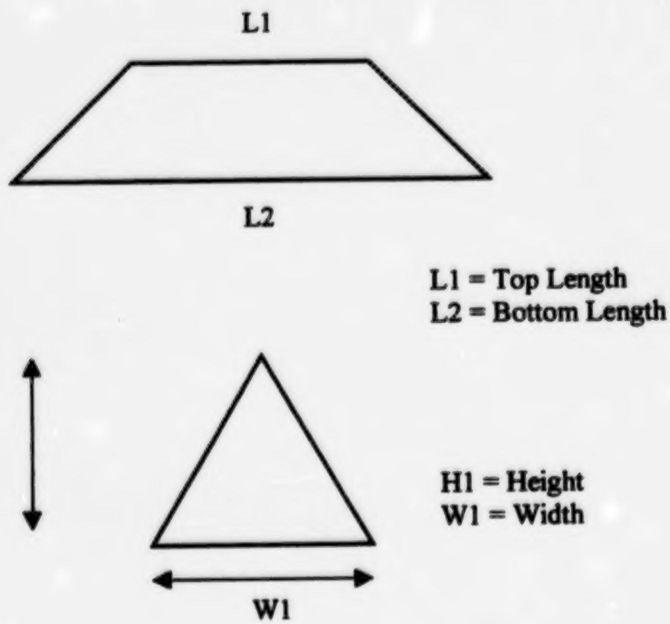


Figure 3-4 Windrow Volume

By tracking the size reduction of the windrows, yard space can be better utilized and predictions can be made as to how much space can be made available in the future. It should also be noted that the volume reduction of different materials are not the same. Each unique feedstock will have its own volume and size reduction properties. Volume reduction also depends on the effectiveness of the composting process.

3.7 CURING

The curing stage of the composting process occurs after the readily available organic matter has been degraded by the microbes. It is at this point where the degradation of more complex molecules within the compost takes place. Large complex organic molecules such as lignin, cellulose, and large molecular weight fatty acids, are usually metabolized during this phase of the compost process.

During the curing phase the need for turning is greatly reduced. However, there is still a need for low levels of oxygen for microbial activity. Therefore, it is necessary to construct curing piles and/or windrows to a size that will allow for passive airflow through the windrow. A recommended size for a curing pile is 1.5 meters tall and 3 – 4 meters wide.

During the curing phase, the windrows should be kept in dry areas, away from excess moisture. Exposure to excess moisture during this phase may cause the curing piles to become anaerobic.

The curing stage of composting is complete when the compost can successfully conform to the CCME guidelines for compost maturity previously mentioned. Compost will not be mature unless it has been properly cured.

4.0 RECORD KEEPING

The Code of Practice for Compost Facilities (Section 11) stipulates that each compost facility must establish and maintain a detailed operating record that can be supplied upon request to Alberta Environment. Each composting facility must also prepare an annual report that includes tonnage records of all materials received and shipped by the facility, as well as compost and surface water monitoring data required by the Code of Practice (Section 8). Accurate record keeping and reporting are not only important responsibilities of the mid-scale compost facility operator, but also serve as very useful management tools.

4.1 FACILITY OPERATING RECORD

The Code of Practice specifies that a Facility Operating Record must be readily available upon request from Alberta Environment and must include a copy of the compost facility's registration, the current design and operations plan, and all annual reports to date. The Facility Operating Record serves as the primary document attesting to the compost facility's adherence to the Code of Practice and thus should be kept current and in good order.

4.2 TONNAGE RECORD

The compost facility should keep a detailed log that characterizes the type, weight or volume, and date of arrival all feedstock and amendment materials received during the calendar year. As well, all compost produced, stored, and shipped out should be similarly described and recorded in an on-going Tonnage Record. A general format for the Tonnage Record is given below (Table 4-1). It is suggested that monthly summaries be prepared if material flow in and out of the composting facility is rapid or highly variable. This practice should greatly facilitate the preparation of the year-end report. These summaries can also be used to identify and quantify monthly or seasonal changes in material type and flow. Tracking these patterns can be helpful for scheduling equipment, labour, and space more efficiently. Moreover, if there is significant variation in feedstock quality or type during specific times of the year, then this information can be employed in planning amendment material needs and optimizing feedstock blends.

Table 4-1. An example of a compost facility's Tonnage Record.

Date	Material Type	Source	Destination	Weight (tonnes)	Volume (m^3)

4.3 Activity Records

Required Activity Records

The Code of Practice specifies that the compost facility must establish a program for monitoring compost processing temperatures (Section 8.1) and surface water quality data, and that accurate records of this information must be kept (Section 11.3). Similarly, a record of ground water monitoring is required if a plan has been established at the written request of the Alberta Environment Director. Activity Records must also include compost analysis results, as specified by CCME Guidelines for Compost Quality, if the compost is intended for "unrestricted use".

Recommended Activity Records

Although not required by the Code of Practice, it is highly recommended that Activity Records be kept for other important process parameters, namely: oxygen level, moisture content, pH, and bulk density. An on-going data base of these parameters, in addition to temperature information, can be used to optimize the compost process management strategy for improved product quality and more efficient production time. On a day to day basis, this information can be used to identify sub-optimal composting conditions and prevent them from becoming problematic.

It is also advantageous to keep track of all changes to the standard process management plan. Recording dates and amounts of all amendments (such as water, fertilizer, and bulking agents) that are made to the composting feedstock will provide invaluable insight that can be used to optimize composting conditions in future batches. Similar benefits can be obtained from logging dates and duration of aeration events.

Another valuable record to maintain is that of feedstock and final compost analysis results. An on-going data base of feedstock and compost properties could be used with other activity records to identify process management practices that are best suited to compost specific feedstock materials into a high quality product.

4.4 Annual Report

The Code of Practice requires that compost facility operators prepare an Annual Report. As previously mentioned this report must include the Tonnage Records and the required Activity Records kept for the calendar year from January 1 to December 31.

4.5 COMPOSTING TECHNOLOGY

As composting is essentially an aerobic microbial process, the maintenance of sufficient oxygen in the pile is imperative. The method of delivering the oxygen to the microorganisms classifies the method of composting.

Five common methods of composting are:

- Static Pile
- Turned Windrows
- Passively Aerated Windrows
- Aerated Static Pile
- In-vessel Composting

STATIC PILE COMPOSTING:

The material is collected into windrows or piles and allowed to decompose over an extended period without mixing.

Because none or very little mechanical agitation is used, the raw material must be initially mixed with a large volume of amendment to afford sufficient porosity for aeration. This is especially the case with manures. Bedded manures with a high concentration of straw can be composted in this manner. The size of the pile or windrow must be small enough to allow for passive aeration to occur.

Occasional remixing and reformation of the pile is beneficial to rebuild the porosity. Sometimes trapped gasses and odors can become a major problem if the piles are not turned periodically.

Passive pile composting takes a longer time to complete due to the low aeration frequency and temperatures. The piles tend to become anaerobic and odorous quickly if porosity is not adequate. Without enough dry amendment, material like manures can form leachate with high concentrations of organic constituents.

Without mixing, there will be areas in the pile which do not attain the required composting temperatures and thus a proportion of the material will not be adequately composted. The outer layer may not undergo composting at all.

Figure 4-2 Natural (passive) air movement in a composting windrow or pile.

Source: On-Farm Composting Handbook, pg. 7

TURNED WINDROW COMPOSTING:

The material is arranged in long narrow piles 3 - 6m wide and 1 - 3.6m high. The width of the windrow is largely determined by the size of the machine used to turn the windrow.

Apart from mechanical turning aeration in windrows can be through passive gaseous diffusion. The size of the windrow for the maintenance of aerobic conditions is determined by the porosity of the material - wet denser material will require smaller windrows than more porous substrates. Large windrows will quickly become anaerobic in the core, requiring constant turning, while windrows which are too small will not attain the required temperatures for efficient composting and the destruction of weed seeds and pathogens.

Mechanical turning of the windrows achieves the following:

- replenishes oxygen to the core of the windrow.
- mixes the material to encourage thorough composting of all the particles and exposure to the hot zone in the core of the wind row.
- restores porosity in the windrow to maintain gaseous exchange.
- blends raw material and increases surface area by particle break down.
- exposes weed seeds, pathogens and insect larvae to the hot inner core of the windrow.
- allows excessive heat, water vapor and gasses to escape.

Low temperatures and odors indicate the need for more oxygen and turning.

Turning frequency depends on the rate of the composting reaction. In the early stages when easily degradable material is being consumed, this could be called for daily. As the process slows down turning frequency is reduced. Temperature, oxygen concentration and odors are good indicators for turning.

Isolated cool regions in the pile (<45°C) indicate that better mixing is required and turning can remedy this. If the temperature is above 60°C, turning will dissipate the heat. If this does not alleviate the problem, smaller windrows need to be constructed.

When windrows shrink they should be combined so as to retain the heat. This is prudent practice in cooler climates. With well managed windrows, the active phase lasts 3 to 9 weeks (depending on the material) after which the curing phase begins.

PASSIVELY AERATED WINDROWS:

In this method the need for turning is eliminated as perforated open-ended pipes embedded across the base of the windrow allow for air to diffuse through the material.

As the material will not be turned (or turned infrequently) particular attention must be given to the size, structure, moisture and porosity of the material when constructing the windrow so as to maintain adequate aeration throughout the process. Amendments which are commonly used to achieve good structure, are straw and wood chips. Peat moss and finished compost can also be used in addition where the primary feed stock has a more slurry-like texture. The use of peat moss can be beneficial. Because peat moss is acidic, odours are reduced and nitrogen is conserved due to less ammonia loss. Because there is no turning, the raw materials must be thoroughly mixed before windrow formation and care must be given not to compact the material while building the windrow.

The windrow can be constructed on a 15 to 20cm high and 3m wide bed of finished compost, straw or peat moss which offers insulation and leachate absorption. The pipes are arranged on top of the bed and a windrow 1.5m high and 3m wide constructed on top of this arrangement. A 15cm layer of peat moss or finished compost insulates the pile, discourages insects and helps with the retention of moisture and reduces odor.

10cm pipes arranged at 30 to 45cm centered intervals along the bed can be used. The pipes have two rows of 1.25cm diameter holes at 30cm spacing along the rows. The rows are at a 60 degree angle and may face up or down.

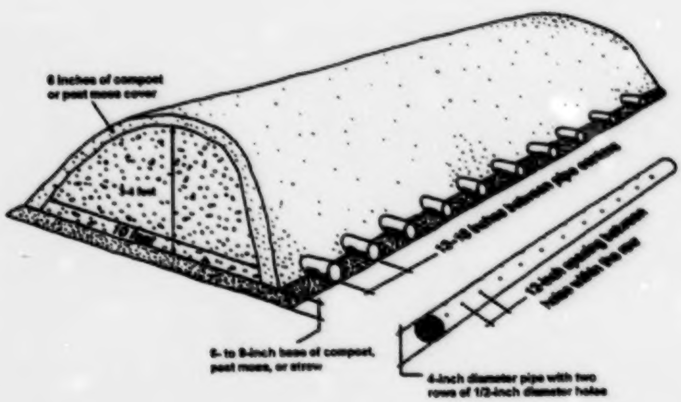


Figure 4-3 Passively aerated windrow method for composting manure.

AERATED STATIC PILE:

In this method a blower is used to force or draw air through the pile. No turning of the material is required once the pile is formed.

As the pile is not turned, particular attention must be given to the blending of the material with structural amendments to maintain porosity throughout the composting period. Wood chips, corn cobs, crop residues, bark, leaves, peat moss, paper and recycled compost may be used to suit the texture and moisture of the primary stock. It is important to achieve a homogeneous mixture and not compact the material with machinery while constructing the pile, so that air distribution is even and no anaerobic areas develop causing sections of uncomposted material.

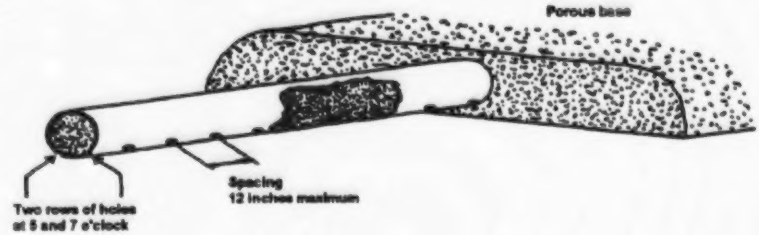


Figure 4-4 Aeration pipe specifications for an aerated static pile

Pile dimensions can be 1.5 - 2.5m high and 3 - 5m wide. Pile length is limited by the air distribution in the aeration pipe and should be less than 21 or 27m (depending on the aeration system) otherwise little fresh air will reach the end of the pipe. Pile height is usually twice the pile width. A 15cm layer of finished compost may be used to cover the material to reduce drying, heat loss, flies and act as a biofilter for odorous gasses.

The perforated section of the aeration pipe is embedded in a porous base of wood chips or straw, 1/4 to 1/3 the width of the pile. The perforated section of the pipe is shorter than the pile by twice the piles' height (3 - 5m shorter than the pile). This is to prevent the air being short circuited out the ends and sides of the pile and not passing through the material of the pile.

Two forms of piles are common - single and extended piles. With single piles the material should be of a single batch or several small batches of the same age (e.g.. within 3 days). This is because a single pipe and blower serves the pile and the material should have the same demand for air throughout to have a homogeneous composting reaction.

Extended piles are used when materials are generated daily and each day's intake is sufficient for a single cell. The cells are built against each other as the material arrives. This results in better use of the pad area. Cell widths are made equal to the pile height and each cell has its own pipe and blower, with the spacing between pipes equal to the pile height. Each blower is controlled by an individual timer or temperature probe for that cell.

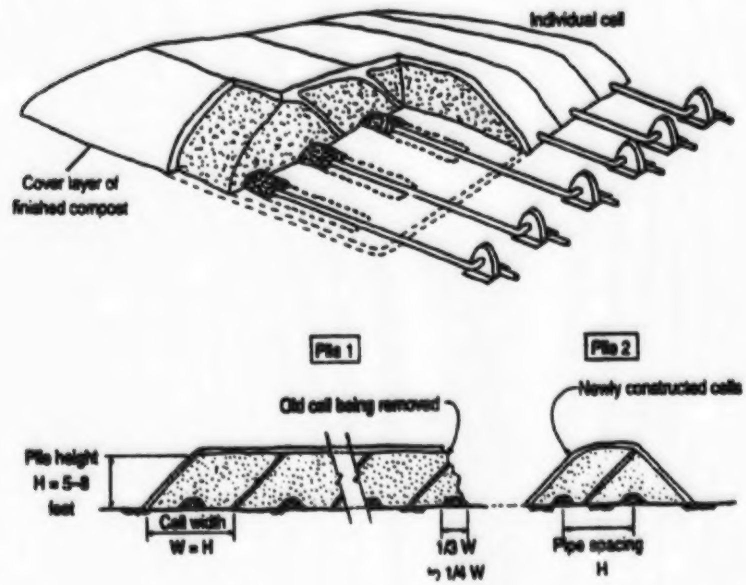


Figure 4-5 Extended aerated static pile layout and dimensions

Air flow can be continuous or intermittent, controlled by a timer or temperature sensor in the pile. Continuous operation allows for lower air flow rates but excessive cooling may result in areas near the perforated pipe. The temperature may never reach levels for the pathogen destruction. With programmed flow operation, the temperatures tend to equalize after the air flow stops.

Table 4-6

Pipe diameter (inches)	Pipe area (square inches)	Hole spacing[b] (inches)	Approximate hole diameter[a] (inches) — Length of perforated pipe[c] (feet): 20	30	40	50	60	70	80
4	12.6	6	5/8	½	7/16	3/8	3/8	5/16	5/16
4	12.6	9	¾	5/8	9/16	1/2	7/16	7/16	3/8
4	12.6	12	7/8	3/4	5/8	9/16	1/2	1/2	7/16
6	28.3	6	15/16	3/4	11/16	5/8	9/16	1/2	1/2
6	28.3	9	1 3/16	15/16	13/16	3/4	11/16	5/8	9/16
6	28.3	12	1 3/8	1 1/16	15/16	7/8	3/4	11/16	11/16
8	50.3	6	1 1/4	1	7/8	13/16	3/4	11/16	5/8
8	50.3	9	1 1/2	1 1/4	1 1/8	1	7/8	13/16	3/4
8	50.3	12	1 3/4	1 7/16	1 1/4	1 1/8	1 1/16	15/16	7/8

Note: Based on a total hole area equal to twice the pipe cross-sectional area.

[a] General formula: hole diameter = $\sqrt{\dfrac{D^2 \times S}{L \times 12}}$ where D = pipe diameter (inches), L = pipe length (feet), and S = hole spacing (inches).

[b] Two rows of holes. Spacing shown is the distance between holes in the same row.

[c] Length of the perforated section of the pipe.

Table 4-7

Sample Calculation: Aerated Static Pile – Aeration System Design

A farm with six hundred head of beef cattle composts manure and straw using an extended static pile with cells 6 feet high and 6 feet wide. The blower is controlled by temperature and operates in the pressure mode. The straw-to-manure rate is 2:1 by volume. Average daily manure production is 24 tons or approximately 800 cubic feet at a moisture content of approximately 85% (15% dry solids).

Estimate the required blower airflow rate and determine the pipe specifications for a daily cell of the extended pile.

Calculate volume of material in the cell

Volume = manure + straw
= 800 ft³ + 1,600 ft³
= 2,400 cubit feet

Note: Mixing several materials together usually reduces the overall volume. The volume reduction which occurs from mixing is often at least 20% of the combined volume of the individual materials. The cell volume calculated above is, therefore, conservative. As a result, the estimated cell length and pipe length may be slightly longer than necessary.

Calculate length of cell (6' high by 6' wide)

Area = height x width
= 6 feet x 6 feet

$\dfrac{\text{Volume}}{\text{Area}}$ $\dfrac{\text{2,400 cubic feet}}{\text{6 feet x 6 feet}}$

$\dfrac{\text{2,400 cubit feet}}{\text{36 square feet}}$ = 67 feet

Calculate estimated airflow rate

Dry weight of manure
= 24 tons (wet weight) x 0.15
= 3.6 dry tons of manure

Estimate air flow =

3.6 dry tones x $\dfrac{\text{100 cubic feet / minute}}{\text{dry ton}}$

= $\dfrac{\text{360 cubic feet}}{\text{minute}}$

Calculate pipe specifications

Estimated pipe size

Area = $\dfrac{\text{360 cubic feet / minute}}{\text{2,000 feet / minute}}$

= 0.18 square feet
= 26 square inches

Diameter = $\sqrt{\dfrac{\text{26 square inches x 4}}{\pi}}$

= 5.8 inches

Use 6-inch pipe.

Pipe spacing = pile height
= 6 feet

Perforated pipe length = pile length – (2 x pile height)
= 67 feet – (2 x 6 feet)
= 55 feet

Pipe hole size/spacing (from table 4.2, page 34)
Use 12-inch spacing with ¾-inch diameter holes

Estimated pressure loss = 2-2.5 inches of water (pile + pipe)

Based on these calculations, the blower should produce 360 cubic feet per minute against a pressure of 2.5 inches of water.

Aerated Static Pile (continued):

For timed blowers, a typical schedule would be 1/2 to 1/3 of the time cycle on, with the off time not to exceed 1/2 hour. The aeration schedule can be adjusted by monitoring the pile temperature. As the temperature rises the on time can be lengthened. When the composting rate and temperature diminish, the off time can be increased.

With a timer, optimal composting temperatures can be exceeded, retarding the reaction. A temperature-based control maintains the pile temperatures at optimal levels e.g. 55 - 60°C and is usually set to 57°C. During start up and when the temperature is below the lower set point of 55°C, the blower is operated by a timer schedule.

Placement of the temperature probe is critical to reflect the average temperature of the entire compost mass. This is usually at 2/3 of the length of the pile from the blower end, 1/3 of the pile height, and at least 50cm deep within the pile. Blowers are usually of the centrifugal axial blade type, ranging from 1/3 - 1/2 horsepower for time control and 3 - 5 horsepower for temperature controlled systems. Blower size will depend on the type and amount of material in the pile, but should be able to provide for the peak air flow rate at the height of the reaction. Selection of the blower also requires the knowledge of the air pressure loss in the system. An odor filter can increase the pressure loss by 3 in. of water. Pressure is less with greater air velocity, higher piles, lower material porosity and smaller and longer pipes.

Pipe holes should be in 2 rows, facing downward, and at an angle of 60° between the rows and with hole spaces no greater than 12in within the rows. The number and size of the holes should provide a total area equal to 2 times the cross sectional area of the pipe. Air must be supplied evenly along the entire length of the pipe and for evenly spaced holes, air becomes less evenly distributed as the pipe lengthens. Thus, for evenly spaced holes, the perforated part of the pipe should not be more than 50ft in a temperature control system and 75ft in a time controlled system.

Air can be blown or sucked through the material. Suction offers the opportunity to treat the exhaust for odor control through a biofilter system. Condensate from the pile must then be collected in a sump before reaching the blower. With sucking there is an increased pressure drop to contend with which will demand a larger blower.

When aeration pipes have to be longer than 50 or 75ft, the blower can be placed in the middle of the pile and a branched pipe used to achieve the required even air flow rate along the entire pile.

With the pressure system little odor control is possible except to increase the thickness of the finished compost layer of the pile. This system provides better air flow from the same blower size and is more effective in cooling, so is preferred when temperature control is paramount.

IN-VESSEL COMPOSTING:

Here composting takes place within a structure, container or vessel with forced aeration and mechanical turning devices.

Bin Composting

The walls of the bin may be constructed of wood slats or concrete blocks. There is usually an air supply manifold of perforated plastic piping laid on the floor to obviate the necessity of frequent unloading, mixing and reloading.

Although bins allow for higher stacking of the material, this can cause compaction and an increased distance for air passage, resulting in anaerobic zones in the upper layers. In this instance, attention must be given to the structure and porosity of the material and adequate operating time for the blower to supply sufficient oxygen and cooling. However, excessive fan operation is likely to dry the material out, thus a fan cycle is chosen to prevent this but provide enough oxygen. The system can be automated to operate the fan on temperature or time.

A sloping floor and drain take care of leachate collection. A series of bins will allow for occasional transfer and mixing which can speed up the process. Bins are often used indoors which allows for better temperature and odor control and eliminating weather effects.

Bunker Composting

These are concrete channels up to 6m wide, 3m high and 50m long with a built in aeration system and leachate collection drain in the floor. A turning machine on rails atop the walls mixes and restores the porosity of the compost.

The compost is at different stages of development along the length of the bunker, so independent temperature sensors and blowers control the temperature and aeration in the different zones. Raw material is loaded at one end and during turning the machine gradually moves the material along the length of the bunker. Treated material is unloaded at the opposite end of the bunker.

Several bunkers can be built side by side with a single turning machine servicing all the units by transferring the machine on a cradle between the bunkers.

The material requires a curing phase after treatment in the bunkers.

Silo Composting

A bottom unloading silo is used. Daily, an auger removes material from the bottom and an equal volume of raw material is loaded at the top. As there is no mixing of the material and it is stacked vertically, thorough blending of the substrate and adequate structural amendment is very important. The aeration system (air blown from the bottom) must also be adequate for sufficient oxygen supply and cooling throughout the vertical height.

Exhaust air is collected from the top and treated for odor elimination. Curing of the product can take place in a second silo or in windrows or piles.

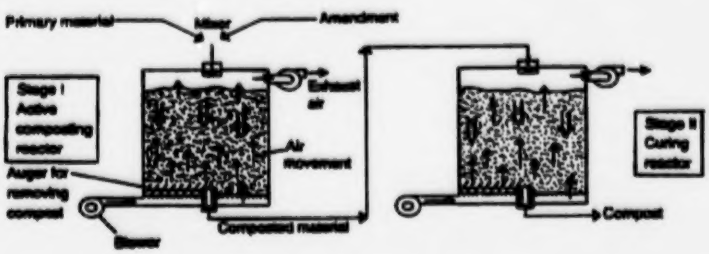


Figure 4-8 Example of a vertical silo composting system

Rotary Drum Composting

This is in effect a horizontal silo mounted on an inclination and capable of rotating about the longitudinal axis. Air is pumped through from the lower discharge end to the higher loading end, moving counter to the composting material and being heated by it along the way. The fresh raw material is thus quickly heated to composting temperatures.

The usual residence time is three days and is controlled by the degree of inclination and the speed of rotation of the drum. Further control is managed by three chambers in the drum, with the contents of each transferred daily into the next as the final chamber is emptied. A sill in each chamber retains 10 - 15% of the compost to serve as an inoculum for the next batch.

As only the labile substrates are digested in the three days spent in the drum, product is screened before proceeding to a secondary composting stage in windrows.

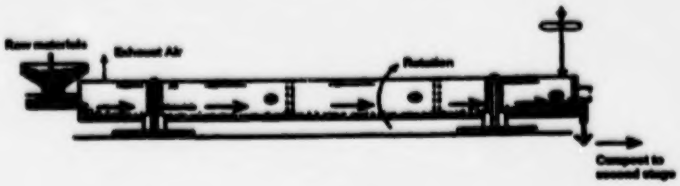


Figure 4-9 A rotating drum composter

Mortality Composting

Composting poultry carcasses by the Maryland method is an adaptation of the Indore method where the raw material ingredients are layered. Typically, for poultry mortality composting there will be alternate layers of poultry litter, straw and then the carcasses in the volume ratio of 2:1:1. This is covered with the next layer of litter to discourage insects. A little water is added to initiate the process. This recipe affords a C:N ratio of 20:1 to 25:1.

Bins can be used for poultry carcass composting. A series of bins is used as this is a two stage process with the material being moved to a secondary bin after 7 to 10 days to achieve homogenization and aeration. The process takes 20 days and temperatures of 55 to 70°C are reached to kill bacteria and viruses. The carcasses are reduced to skeletal remains.

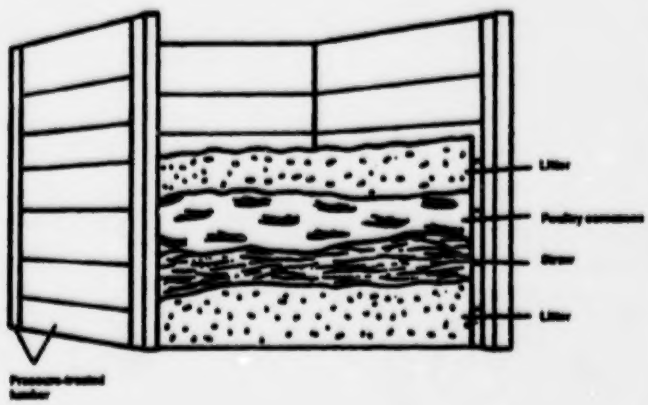


Figure 4-10 Poultry carcass composting bin

Comparison of Composting Methods

In-vessel composting, with its high capital costs, is limited primarily to large centralized composting facilities. Farm and mid-scale composting endeavors can utilize windrows, static piles (non-aerated and aerated) bins and simpler bunker systems.

	ADVANTAGES	***DISADVANTAGES***
TURNED WINDROWS:	No electric power required. Existing farm machinery can be used. Greater choice of amendments possible. Turning mixes and reduces the need for grinding and screening. Mechanical breakdown particles – process occurs more rapidly.	Labour intensive. Extensive land required. Loss of nitrogen occurs. No odor control. Weather influenced.
STATIC PILES:	Less nitrogen loss than turned windrows. Some odor control. Existing farm machinery can be used. Relatively inexpensive.	Labor peaks at formation and breakdown of piles. Less choice of amendments. Material must be well mixed and sized from the start.
AERATED PILES:	Odorous can be collected and treated. Closer process control. Better parthogen destruction. Easily automated. Shorter process. Less land is needed as piles can be bigger.	Electric power required. Labor peaks at formation and breakdown of piles. Limited choice of amendments. Material must be well mixed and sized from the start.
IN-VESSEL COMPOSTING:	Reduced labor. No weather problems. Odor control. Better process control. Fast composting. Less land required. Consistent product quality. Contained system to reduce potential for contamination.	High capital cost. Operating and maintenance expertise required.

5.0 Composting Process Optimization

5.1 Equipment

Windrow Turners and Windrow Turning

When composting, it is important to incorporate oxygen into the composting material. This may be achieved by using a windrow turner. Windrow turners come in all shapes and sizes, and use several different methods of introducing oxygen into the windrows. Therefore, it is most important to choose the proper size of windrow turner, and the windrow turner that utilizes the best turning method. Factors which aid in the choosing of a windrow turner may be based upon the volume materials to be composted and the nature of the feedstock itself.

Some of the various methods used to turn windrows include, rotary drum turners, elevated face turners, or auger turners. Each of these methods may employ one of three types of movement. The turner may be self propelled, a tow behind model, which would necessitate the use of a tractor, or it may be a bucket mounted model, which would also necessitate the use of a tractor or loader.

Many rotary drum turners straddle the windrow and as they move in a forward direction the rotating drum stirs the windrow. This rotating drum actually aids in the particle reduction of the material. An elevated face turner aerates the windrow by lifting the material and dropping it. Auger type windrow turners aerate the windrow by actually displacing the windrow and moving it to one side.

Tractors, loaders, and skidsteers may also be used to turn windrows. This, however, may require a bit more time than a turner, but operators can utilize the equipment that is already at hand. There are a few different ways to turn windrows with the above mentioned equipment. One way is to pick up a bucket of material and to reform a new windrow beside the windrow being turned. Another is to reform a new windrow several meters in from of the windrow being turned, in essence moving the whole windrow forward several meters, one bucket at a time.

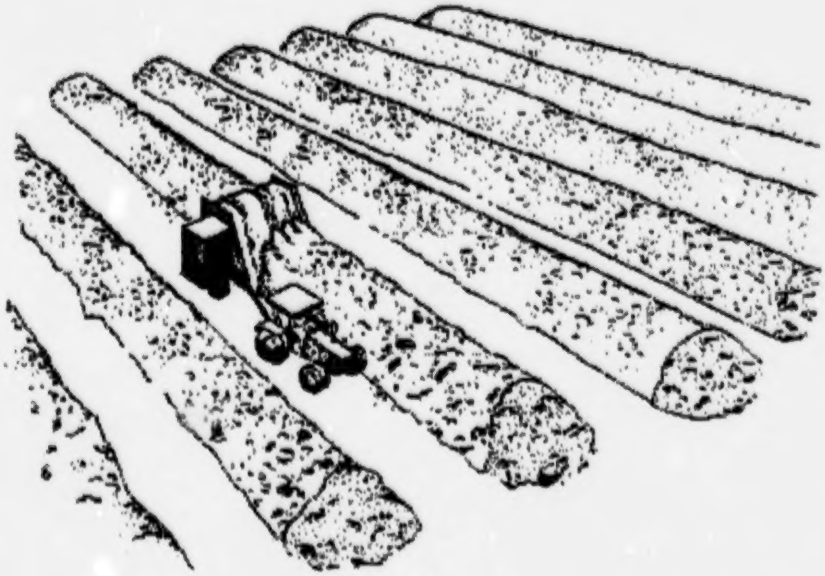


Figure 5-1 **Windrow composting with an elevating face windrow turner.**

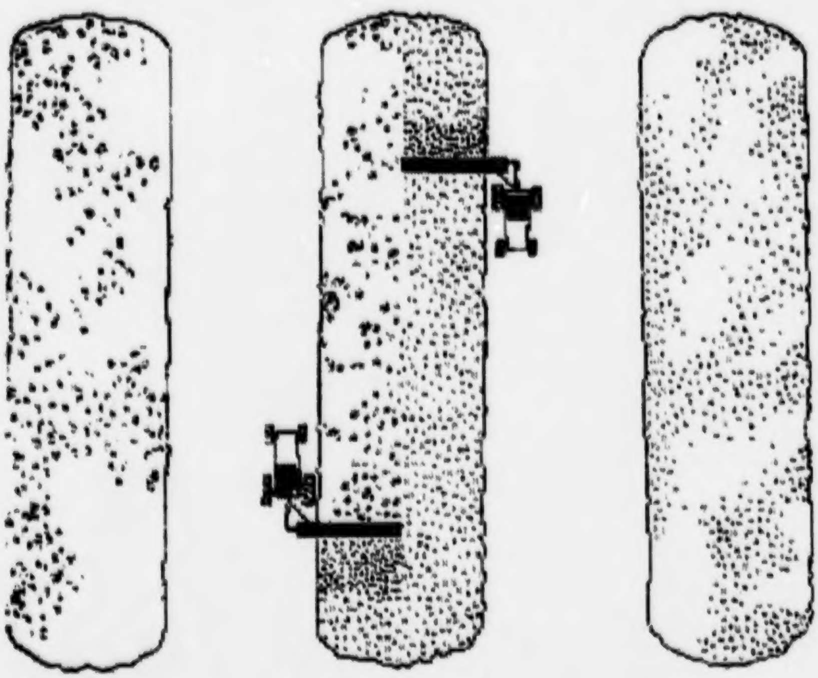


Figure 5-2 **Two Passes are necessary for most Tractor-drawn Turners.**

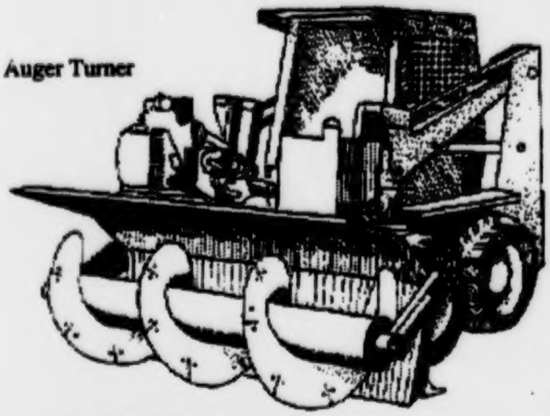


Figure 5-3 Self propelled auger tuner

Source: On-Farm Composting Handbook, pg. 25.

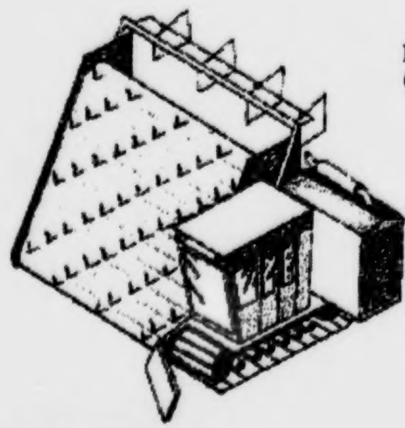


Figure 5-4 Self propelled elevating face turner

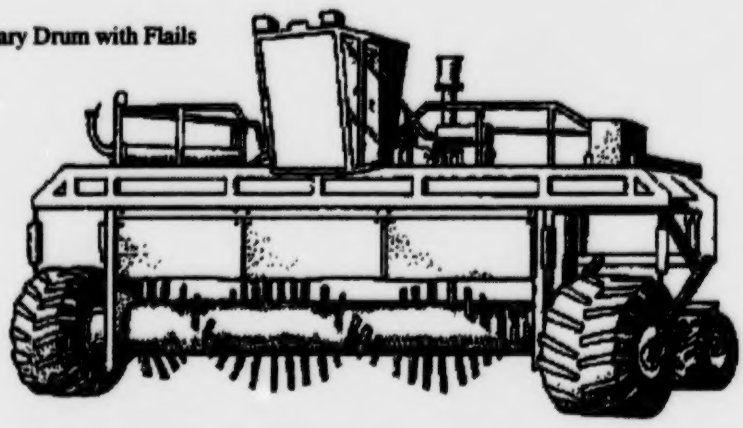


Figure 5-5 Straddle type self propelled windrow turner

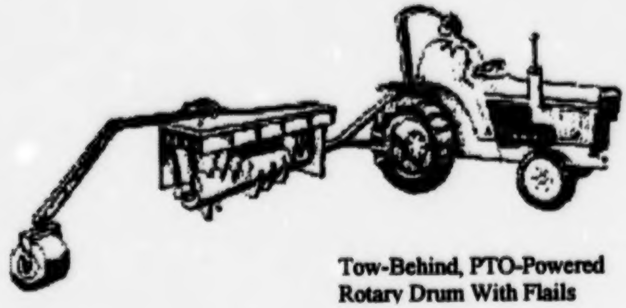


Figure 5-6 **Tractor-Assisted Windrow Turner.**

Source: On-Farm Composting Handbook, pg. 27.

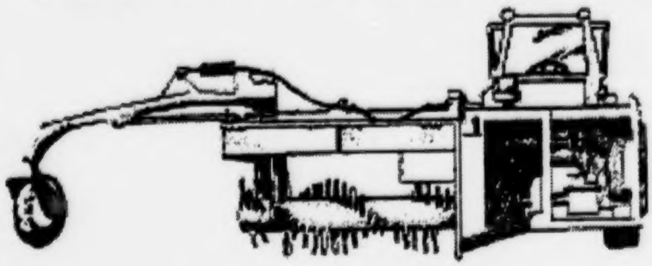


Figure 5-7 Push-Type, Self-Powered (diesel engine) Rotary Drum

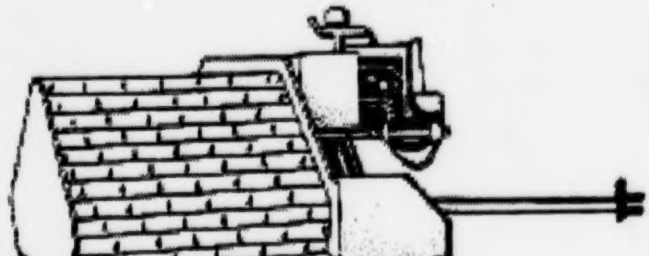


Figure 5-8 Tractor-Assisted Windrow Turners.

Source: On-Farm Composting Handbook, pg. 27.

LOADERS:

Loaders are the most versatile piece of equipment in compost facilities.

There are three primary uses for loaders and skidsteers:

1. windrow construction
2. windrow turning
3. edging windrows after turning with a windrow turner

Loaders and skidsteers come in a wide variety of shapes and sizes. Therefore, it is important to choose the appropriate piece of equipment for the work that needs to be done.

When using a loader for the construction and turning of windrows, a loader with a large bucket capacity should be used in order to minimize the amount of time necessary to either construct or turn a windrow. Medium sized loaders and larger sized skidsteers work well in this regard. During the construction of windrows with either loaders or skidsteers, an important aspect to keep in mind is the spacing between windrows. The spacing between windrows should be one and a half to two times the width of the loader or skidsteer bucket. This will make the edging of turned windrows much easier as there will be sufficient room to maneuver between the windrows.

Source: On-Farm Composting Handbook, pg. 26.

Figure 5-9 Turning Windrows Using a Bucket Loader.

5.2 MONITORING INSTRUMENTS

For the most efficient, rapid and complete composting reaction to occur, environmental conditions that favour the appropriate aerobic microorganisms at each step of the process in the pile must be established and maintained.

REQUIRED ENVIRONMENT FOR RAPID COMPOSTING:

	REASONABLE RANGE	PREFERRED RANGE
C:N	20:1 - 40:1	25:1 - 30:1
% Moisture Content	40 - 60	50 - 60
% O_2 Concentration	>5	>12
pH	5.5 - 8.5	6.5 - 8.0
Temperature (°C)	45 - 65	55 - 60
Particle Size (cm.)	1 - 5	1 - 2.5
Bulk Density (kg/m³)	550 - 850	600-700

Adequate monitoring of these parameters can be accomplished with a few relatively simple and inexpensive instruments.

When temperatures reach the upper limit (70° C) the compost should be turned to ensure an optimum environment for the microbes.

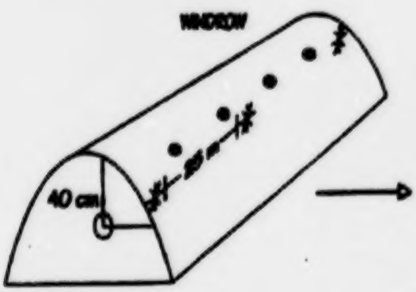
TEMPERATURE:

Dial thermometers with 1m stems or portable digital temperature probes are available for monitoring temperature in compost piles.

Measurements should be taken at 15m intervals along the windrow to reflect the overall activity of the pile. A minimum of 3 temperature measurements should be taken for each windrow.

Semi-permanent thermocouple wires can also be inserted into the core of the windrow. Using this method, temperatures are always taken from the same spot and collecting the data is faster, an important consideration in a large facility with many windrows.

Temperature is monitored by the use of a long stem thermometer at depth and distances throughout the windrow sufficient to give a good cross section of the entire pile.



• = sampling positions on alternate sides of windrow

Ensure you take temperatures at the core of the pile.

Figure 5-10 The number of sampling points required per windrow is dependant on the volume.

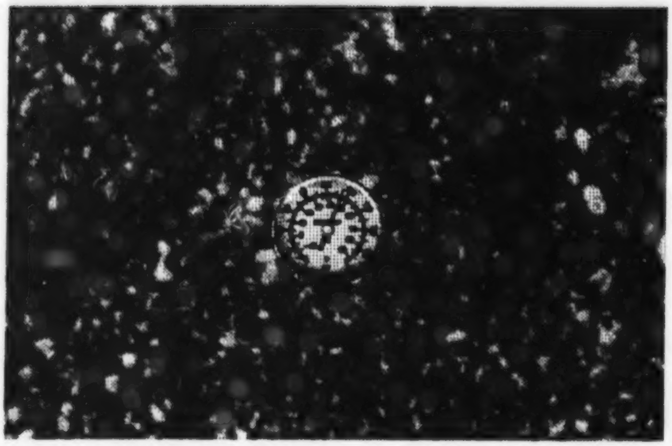


Figure 5-11 This is a dial thermometer inserted into a compost pile.

Table5-12 Example of a data sheet for monitoring temperature of a windrow.

DAILY MEASUREMENTS

Project Name:
Project Code:

			TEMPERATURE				
Date	**Day**	**Ambient**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**	**Average**
	0						
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						

OXYGEN:

Oxygen meters with long probes are used for measuring oxygen in compost piles.

The probe is inserted into the core of the pile and a gas sample is drawn into the oxygen cell where the oxygen concentration is determined. A read-out device shows the concentration of oxygen in the windrow.

Calibration of the oxygen cell uses an ambient air sample, which has an oxygen concentration of 21%.

Samples are taken from the same positions where the temperature measurements were done to give an accurate reflection of the condition of the composting environment.

Figure 5-13 This is an example of an Oxygen meter with an aspirator bulb.

pH:

The broad spectrum of different ecological types of microorganisms involved in composting allows the composting process to work over a wide pH range. A fluctuation in pH values in composting environments may limit the activity of certain microorganisms. A starting pH close to neutral (pH 7) is desirable.

pH is especially important with raw materials that have a high nitrogen content and which usually have an alkaline pH. A pH above 8.5 tends to lead to the loss of nitrogen as ammonia. A pH lower than 8.0 will reduce the loss of this important nutrient and ameliorate the formation of noxious odors.

In the early stages of the reaction the formation of organic acids will depress the pH temporarily.

pH measurements are performed on a composite sample formed into a saturated paste (30g. sample + 30ml. distilled water thoroughly mixed and allowed to steep in a covered beaker for 4 hours). The pH meter is calibrated to pH 7 and pH 10 buffers before determining the sample pH.

SIMPLE pH TESTING METHOD

Saturate the compost sample with distilled water, letting the compost settle and take the pH by conducting a litmus test.

CONTROLLING pH:

During composting the pH does not change much. The pH should be controlled during recipe formulation and initial blending stage. Usually if feedstocks are too acidic, the addition of lime would raise the pH closer to neutral.

pH

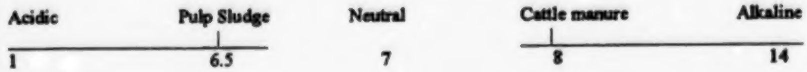


Figure 5-14

Moisture:

Water is necessary for the metabolic processes of the microorganisms in the compost pile. It also serves as a holding and transport medium for nutrients and microorganisms.

The optimal moisture range for composting is 40 - 65%. Below 15% microbial metabolism is inhibited. Above 65% water displaces air in the micro pores of the material and anaerobic conditions are apt to prevail and there is a risk of excess leachate and anaerobic conditions.

A starting moisture level of 50 - 60% is recommended because the heat of the compost reaction will evaporate a lot of water. Dry material is mixed with wet material to achieve this initial value. As water is lost during the process, more water is added during routine turning to maintain the sufficient value.

Some organic materials can hold more water than others without causing anaerobic conditions.

The moisture content can be determined by drying a compost sample in a 60° C oven for 24 hours. The following formula is used to calculate the moisture content for this method:

$$\% \text{ Moisture} = \frac{\text{Mass wet sample} - \text{Mass dry sample}}{\text{Mass wet sample}} \times 100$$

A microwave oven can also be used for quick results. However, avoid charring the sample by stirring intermittently and using short cooking times.

A squeeze test can rapidly estimate moisture content for compost. If the compost feels like a wet sponge it is about 50%. If the compost is too dry it will crumble in your hand, if it is too wet it will drip.

Typical feedlot manure has a bulk density of 850kg/m³

Bulk Density - Bulk density is expressed in weight per unit volume. Bulk density will tend to increase as the composted materials structure breaks down, however, moisture content of the material may lead to false conclusions (the more water retained in the compost the heavier it will appear). In order to measure bulk density: take a container of known volume, fill the container with compost, weigh the container with compost, record your results as kg/m³.

BULK DENSITY:

This is the measurement of the mass of material, including the air spaces, occupying a given volume. It reflects the compaction of the material as well as the overall particle size and proportion of air spaces in the material. The greater the bulk density, the smaller the particle size and air spaces will be and the more mass of substance will be present in the given volume. For adequate composting the bulk density should not be greater than 650kg/m³.

In order to achieve the desired bulk density for initial composting, feedstocks with different bulk densities should be mixed together. Typical bulk density of wood chips for example is approximately 350kg/m³. This is too low for composting and should be mixed with materials with a higher bulk density. If 1 part of wood chips was mixed with 1 part of sewage sludge, with a bulk density of 950kg/m³. the resulting mix will have a bulk density of 750kg/m³.

Table 5-15

Bulk Density Data Sheet

Project #:			**Project Name:**			
Start Date:			**End Date:**			
Date	**Sample**	**Wet Wt. (kg)**	**moisture (%)**	**Dry wt (kg)**	**Volume (L)**	**Bulk Density (kg/m³)**
example	pulp sludge	12.8	63.8	4.634	20	231.68
example	soil	50	63.8	18.100	20	905.00
example	soil	50	75	12.500	16	781.25
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
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				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0

5.3 Monitoring Frequency

Temperature and oxygen concentrations need to be measured more often than moisture and pH, as the former two parameters indicate directly the composting performance. Moisture and pH need only be done at weekly (or longer) intervals.

Depending on the rate of activity and with very reactive substrates, temperature and oxygen determinations might be required daily in the preliminary high reaction phase. As the reaction rate decreases, monitoring intervals will be gradually extended to once a week or longer and still afford precise control of the process. The following is a schedule of the types of tests that need to be conducted during feedstock preparation, composting, stabilization and curing phases.

An initial analytical test of compost feedstock chemical parameters is as follows: Moisture, TN, P, K, S, Ca, Mg, Na, Zn, B, Mn, Cu, Fe, Mo, Al, TC, pH, E.C., Ash, OM, SAR, C/N. This information is useful for recipe formulation and determination of the quality of the finished compost.

Table 5-16: Suggested frequency for monitoring Composting Parameters

	C/N Ratio	Volume & Weight	pH	Temperature Ambient	Temperature Core	Oxygen Content	Particle Size	Odour	Bulk Density	% Moisture	Trace Element
Individual Feedstocks	x	x	x				x		x	x	x
Combined Feedstocks	x	x	x				x		x	x	
Daily Measurements				x	x						
Weekly Measurements			x			x		x	x	x	
Finished compost x										x	

Figure 5-17:

Initial and Final Measurements

Parameters	Date	Start	Date	Finish
CHEMICAL				
C/N Ratio				
pH				
EC				
N				
P				
K				
Trace Element				
Analysis				
PHYSICAL				
% Moisture				
Bulk Density				
Particle Size				
Temperature				
Ambient Temperature				
Volume				
BIOLOGICAL				
Cress				
Growout				

5.4 TURNING FREQUENCY

Turning has the following effects:

- Replenishes oxygen in the interstitial air spaces. This can be quickly consumed in active piles.
- Pile material has the tendency to collapse, diminishing the size of the air spaces. Turning restores the air spaces within the pile to allow for more efficient convection of fresh air through the pile. This is a more long lasting remedy than item 1.
- Mixes the material from the cooler outer layers towards the hotter core so that all portions of the material are exposed to the optimal composting temperatures
- Mechanically shreds the material to smaller particles. Care should be taken not to have too small a particle size otherwise anaerobism can set in very quickly.
- Can be used to cool a pile when too hot, or when adding water, turning is imperative to blend in the water homogeneously.
- Can also remove excess water vapor, obnoxious odors and other gasses.
- Disrupts the fly breeding cycle by transferring ova and larvae from the cooler surface layers to the hot core zone where they are thermally destroyed. This is accomplished by turning every 5 days during fly season.

Turning frequency depends on the rate of decomposition. In the beginning high rate phase this could be a daily requirement. As the process continues and nutrients are depleted, turning can be gradually reduced to once a week or less, depending on the temperature and oxygen levels.

Composting must take place under aerobic conditions because anaerobism selects for microorganisms with undesirable biochemical reactions which are less efficient at heat production and also result in an accumulation of compounds which have obnoxious odors and are phytotoxic e.g. hydrogen sulfide. A minimum oxygen concentration of 5% is required to avoid these pitfalls.

The natural convection and evaporative rate for the removal of excess heat from the windrow is greater than that for the replenishing of the required oxygen. Therefore temperature is more often used to determine the turning schedule. Turning is called for when the temperature rises above 60°C.

A steady drop in temperature over four or five consecutive days might indicate a depletion of nutrients in the hot zone which turning can remedy by replenishing the active core with less degraded material from the cooler mantle of the windrow.

Intermittent cool and hot spots along the windrow may indicate unevenly mixed material which turning can eliminate.

5.5 SAMPLING

Because composting deals with a solid matrix having a myriad of non continuous materials agglomerated into particles of relatively large size, collecting a sample which reflects the overall quality of the pile material can be problematic.

A composite sample should be used for testing. A composite sample consists of samples of the same volume collected from different locations and depths in the pile. These are then thoroughly mixed and then sub-samples extracted for the various analyses.

Routine sampling for moisture and other parameters should be carried out by collecting samples from the core of the windrow. The core is most representative of the overall composting activity.

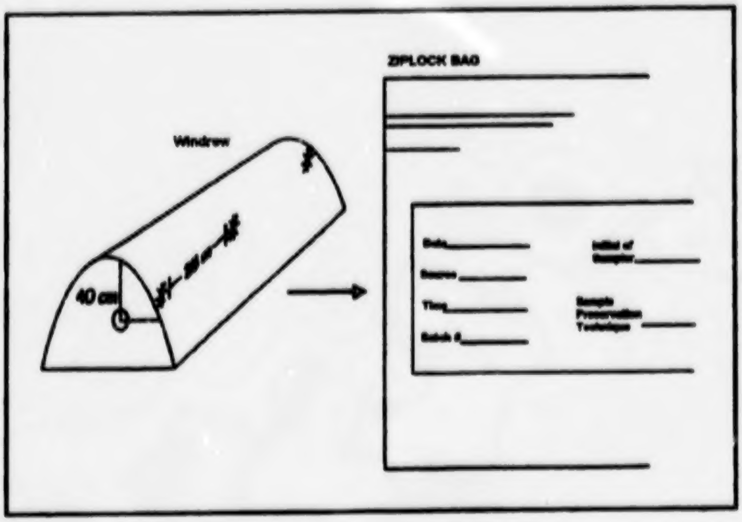

***Figure 5-18:** Material for sampling is generally collected from at least 3 spots on the windrow.*

5.6 COMPOSTING TEMPERATURES

Microbial metabolism in the pile results in a temperature increase as free energy is released when the microorganisms enzymatically break down the nutrients in the material. This increase in temperature is due to the insulating properties of the pile material. The optimal temperature range for rapid and complete composting is 55 - 65°C. These thermophilic temperatures are also desirable for the destruction of pathogens, insect larvae and weed seeds.

Nitrogen immobilization occurs when materials with a high C:N ration are land applied. The microorganisms that use the carbon also assimilate the available nitrogen, making it unavailable to plants.

Upon mixing the feedstock together the windrow will not start to heat up for a few days. This is called the "Lag Phase". During the lag phase there are low levels of microorganisms and therefore no heat is generated. Once the microorganisms start to grow they will multiply rapidly and result in a very quick rise in temperature. This is called the "Log Phase", since microbial populations are increasing logarithmically.

Once all the microbial populations become established a period of stable composting temperatures follow for about 4 – 5 months. During this stage composting activity is maintained at a high rate and composting temperatures are maintained within the range of 45 – 65°C. This is the "Active composting phase". Once the organic matter is decomposed by the microbial activity composting temperatures start to decline. This indicates the start of the "Curing Phase". During curing the composting temperatures drop to ambient levels and should not reheat upon turning. Curing the composting is an important phase of the composting process because the beneficial soil microbes begin to dominate the compost and other microbes die off.

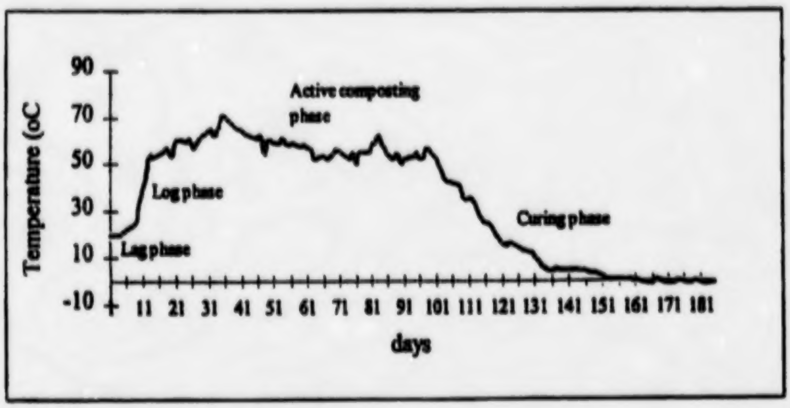

Figure 5-19 Typical temperature profile for windrow composting.

In very active piles, temperatures can rise to above 70°C, at which point many of the beneficial composting microorganisms cannot survive and the reaction slows down or ceases. To prevent this from happening, turning or increased aeration to cool the windrow is necessary.

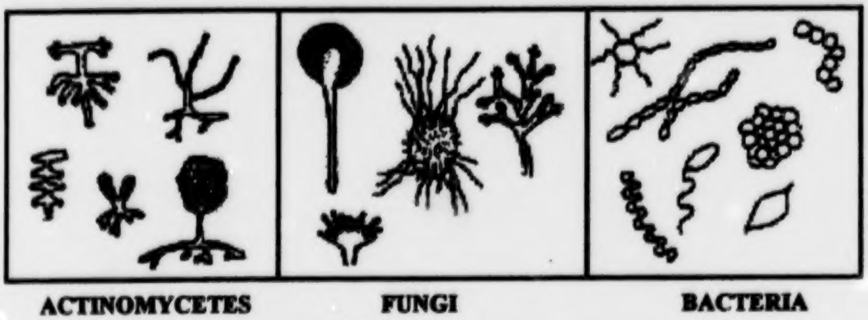

Figure 5-20 Examples of different microbes.

The three main groups or microorganisms found in composting piles are:

- bacteria
- fungi
- actinomycetes

Bacteria are the most numerous organisms in the composting pile and are found in many forms. Bacteria can be classified according to the temperature at which they can survive and reproduce. The three main types of bacteria are psychophilic, mesophilic and thermophylic. These organisms are small and tend to be generally faster decomposers than other microbes.

Fungi are larger microorganisms and are also present in many forms. Fungi take over in the final stages of composting when the organic material has been changed to a more digestible form. They tend to thrive in a lower pH range and are tolerant of low-moisture conditions. Fungi are also able to decompose woody materials that are generally resistant to decay.

Actinomycetes are a higher form of bacteria, similar to fungi and mold, common in the early stages of the pile. Actinomycetes can be recognized by greyish, cobwebby growths that give a pleasing earthy smell to compost. The liberation of carbon, nitrogen and ammonia takes place in the presence of this type of bacteria. They are most often found in drier parts of the pile and can survive a wide range of temperatures and conditions. Actinomycetes will take over during the final stages of decomposition, often producing antibiotics, chemical substances that destroy other bacterial growth.

As the simpler compounds in the material (usually monosaccharides) are depleted by bacteria, they die off. Fungi, have the necessary enzyme systems to break down the more complex substances (polysaccharides) become more prominent and the temperature decreases as the reaction slows down.

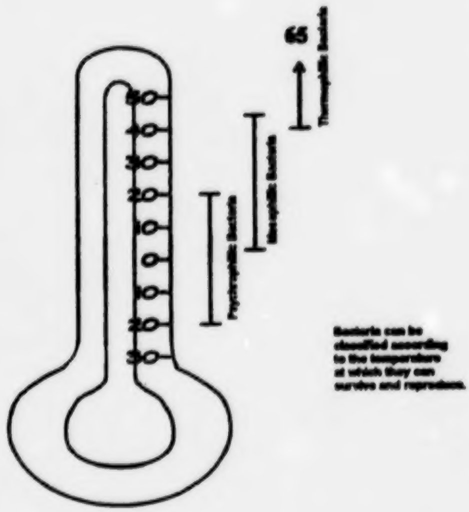

Figure 5-21

Composting microorganisms can be grouped into 3 arbitrary temperature ranges:

Psychrophilic	<20°C
Mesophilic	10 - 45°C
Thermophilic	>40°C

As the pile temperature fluctuates through these ranges, a dynamic hierarchical progression of successive microbial cohort types occurs, each with an increasing optimal temperature, living off the residual of the substrate and the carcasses of the microbes that have died off.

To quickly achieve and maintain the optimal thermophilic temperature range, a minimal pile size is required, otherwise the metabolic heat generated dissipates and the pile does not heat up. Excess moisture can also delay pile heat up.

For the curing phase in colder climes, an insulating layer of straw or finished compost can be used to maintain the inner core at higher temperatures to prolong the reaction, or piles can be combined to create a larger mass which will cool down slower.

5.7 TROUBLE SHOOTING PROCEDURES

	Symptom	Possible Cause	Remedy
1.	Smells like rotten eggs (H2S)	Anaerobic condition due to excessive moisture.	Add dry porous material and turn pile.
		Anaerobic condition due to compaction.	Add structural amendment (wood chips) and turn pile.
		Anaerobic condition due to overlarge windrow.	Construct smaller windrow to facilitate aeration.
2.	Smells like ammonia odor.	Too much nitrogen.	Add carbon source (wood chips, straw) and turn pile.
3.	Pile does not heat.	Pile too small.	Construct larger pile.
		Pile too dry.	Add water and turn.
		Poor aeration.	Turn pile.
		Lack of nitrogen.	Turn in high nitrogen source (manure, fresh grass, fertilizer).
		Cold weather.	Increase pile size or insulate with layer of straw or mature compost.
4.	Temperature too high. (>60°C)	Pile too large.	Reduce pile size.
		Insufficient ventilation.	Turn pile.
5.	Pile is damp and does not have a bad odor but will not heat up.	Lack of nitrogen.	Mix in high nitrogen materials such as grass clippings or inorganic nitrogen fertilizer.
6.	The centre is dry.	Not enough moisture.	Add water while turning the compost pile to reach moisture levels of 50-55%.
7.	Insect larvae.	Seasonal	Turn every 5 days to break life cycle. Cover with compost.
8.	Vectors/rodents	Unattended windrows.	Maintain active composting.

6. COMMUNITY RELATIONS

Education and awareness in a community goes a long way towards public acceptance. When the benefits and the environmental advantages of composting are identified to the community and society as a whole, often communities and individuals will accept the composting program more readily. Some of the specific community relations considerations when setting up a mid-scale composting site are:

- site selection - location, feedstock availability, previous use of the site, political acceptance, transportation access, volumes and community support
- prompt handling and appropriate amendments
- regulations
- community involvement at the facility
- leachate collection & treatment system
- compost capping
- use of a compost biofilter
- demonstration days to increase awareness
- odor-masking aerosols
- participate at community events
- compost sales

6.1 ODOUR CONTROL

The use of compost in Alberta is almost entirely determined by the nature of the compost and the composting facility. The public generally favors composting over other waste management options. However, many individuals, as well as communities, do not want composting facilities or other waste handling industries in their neighborhoods. In the United States large facilities have been closed down due to odour problems caused by poor design and lack of management.

Some suggestions for odour control are as follows:

Proper process management will assist in controlling odour problems, such as keeping materials aerobic, which happens by turning frequently at the initial stages of composting and capping windrows with more mature compost. Another possibility is to use covers for compost piles and windrows. This is more costly and depends on the climate in your area. Composting in a covered building is another mechanism that will assist in controlling odours.

6.2 NUISANCE CONTROL

Decomposing organic matter can attract vectors, which include flies, mosquitoes, fleas, rodents, and birds. Keeping the piles capped or covered so that raw materials are not left exposed, reduces the attraction of vectors. Turning the windrows every 5 days during the fly season will break the life cycle of the larvae and aid in pest control.

6.3 COMPOST SALES

Sales of compost to the local community encourages people to use compost products in their gardens and yards and increases the awareness that waste can be converted to a valuable resource. The acceptance of the compost product greatly influences how the community views the composting facility. Even though selling compost in the community may not be the main market, this activity will encourage the acceptance and support for the facility.

Some considerations for selling the compost to the local community:

- what is the end use of the compost
- will you be selling bulk or bagged
- educate the people on how to use the compost
- ensure the compost is of high quality
- provide specifications of material sold

The local community may only purchase a small portion of the volume of compost.

Before financing a private facility, a lending institution wants assurance that a market for the finished product exists. Past experiences have shown that a high quality product can be more easily marketed.

Prices generally vary from $10 to over $20 per cubic meter. The principal paying markets in Canada are nurseries, greenhouses, parks and recreation areas, and soil blenders. Currently, marketing of compost for agricultural purposes is fairly new in Canada and the economics of large volumes will play an important role in the success of this market.

APPENDIX A

ADDITIONAL RESOURCES AND CONTACTS

- Alberta Environment: *"Code of Practice for Compost Facilities"* - order from Queen's Printer Bookstore, 11510 Kingsway Ave. Edmonton, AB T5G 2Y5 (403) 427-4952 phone or (403) 452-0668 fax
- Alberta Environment: *"A Full Cost Analysis Guide for Municipal Waste Managers" (1994)*
- The Composting Council of Canada: *"Composting Technologies & Practices"*
- CCME Canadian Council of Ministers: *"Guidelines for Compost Quality"* - order from CCME documents c/o Manitoba Statutory Publications of the Environment, 200 Vaugh Street, Winnipeg, MB (204) 945-4664 phone or (204) 945-7172 fax
- Composting Technology Centre, Olds College: *"Compost in a Crate"* - (403) 556-4745 phone or (403) 556-4718 fax
- Alberta Environment: *"Leaf and Yard Waste Manual"*
- Science of Composting: *Eliot Epstein 1998, Technomic publications.*

Composting Websites:

The Composting Council of Canada

www.compost.org

Olds College

www.oldscollege.ab.ca

APPENDIX B

DEFINITIONS

Aeration	The process by which the oxygen-deficient air in compost is replaced by air from the atmosphere. Aeration can be enhanced by turning the compost, by passive aeration or by forced aeration using blowers.
Aerated Static Pile	A composting system in which a heap of feedstock is formed and subjected to forced or passive aeration to provide the aerobic biological decomposition of the organic matter.
Bulking Agent	An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (e.g. straw or wood chips).
Carbon-to-Nitrogen Ratio	The ratio of the percentage of carbon (C) to that of total nitrogen (N) in organic materials.
CCME	Canadian Council of Ministers of the Environment
Co-composting	Composting two or more distinctly different materials together, generally as a strategy for achieving a better balance of carbon and nitrogen, or favourable moisture content. Usually refers to the composting of solid wastes, which are relatively dry and carbon-rich, with wet sewage sludge, which is rich in nitrogen.
Compost	A stable humus like material that results from the biological decomposition and stabilization of organic materials under aerobic and thermophilic conditions. Compost is potentially beneficial to plant growth, and is sanitized to a degree that protects human and plant health.
Composting	Biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost.
Contaminant	A contaminant is an element, compound, substance or organism, which through its presence or concentration causes and adverse effect on the nature, environment or impairs human use of the environment.
Contamination	Any introduction into the environment (water, air or soil) of microorganisms, chemicals, wastes or wastewater in a concentration that makes the environment unfit for its intended use.
Curing	Final stage of composting in which stabilization of the compost continues but the rate of decomposition has slowed to a point where turning or forced aeration is no longer necessary. Curing generally occurs at lower, mesophilic temperatures. Used synonymously with maturing.
Degradability	Term describing the ease and extent that a substance is decomposed by the composting process. Materials which break down quickly and /or completely during the time frame of composting are highly degradable. Materials which resist biological decomposition are poorly or even non-degradable.

Foreign Matter	Any matter resulting from human intervention and made up of organic or inorganic components such as metal, glass, synthetic polymers (e.g. plastic and rubber) that may be present in the compost.
Feedstock	Materials that contain organic materials that decompose biologically.
Heavy Metals	A group of metallic elements that include lead, cadmium, zinc, copper, mercury and nickel. They occur in small quantities in all soils and can be found in considerable concentrations in sewage sludge and several other waste materials. High concentrations in the soil can lead to toxic effects in plants and animals ingesting the plants and soil particles. Federal and provincial regulations restrict the land applications of materials that contain high concentrations of heavy metals.
Humus	The dark or black carbon-rich, relatively stable residue resulting from the decomposition of organic matter.
Leachate	The liquid that results when water comes in contact with a solid and extracts material, either dissolved or suspended from the solid.
Lignin	A substance that, together with cellulose, forms the woody cell walls of plants and the cementing material between them. Lignin is resistant to decomposition.
Mesophilic	Operationally, the mid temperature range most conducive to the maintenance of optimum digestion by mesophilic bacteria, generally accepted as between 20 and 45°C
Microorganisms	A living organism so small that it requires magnification before it can be seen.
Mid-scale Facility	A Class I compost facility that accepts between 20,000 tonnes and 500 tonnes of waste per year.
Moisture Content	The fraction or percentage of a moist substance that is water.
MSW	Municipal Solid Waste
N.P.K	The chemical symbols for Nitrogen(N), Phosphorus(P) and Potassium(K)
Pathogen	Any organism capable of producing disease or infection. Often found in waste material, most pathogens are killed by the high temperature of the composting process.
pH	A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Thus something that has a pH of 8 has ten times fewer hydrogen ions than something with a pH of 7. The lower the pH, the more hydrogen ions present, and the more acidic the material is. The higher the pH, the fewer hydrogen ions present, and the more basic it is. A pH of 7 is neutral.
Phytotoxic	An adjective describing a substance that has a toxic effect on plants. Immature or anaerobic compost may contain acids or alcohols that can harm seedlings or sensitive plants.

Pilot Program	A scaled-down version of a planned program designed to test the operation on a sample of the material or of the population involved, as a means of verifying numerical data or other assumptions used in the system design before committing greater resources to the full-scale operation
Source Separation	Separation of the waste materials into two or more distinct components prior to collection to limit the possible contamination of one material stream by the other.
Stability of Compost	The reduced rate of change or decomposition of compost as it approaches maturity. Usually stability refers to the lack of change or resistance to change. A stable compost continues to decompose at a very slow rate and has a low oxygen demand.
Thermophilic	Heat-loving microorganisms that thrive in and generate temperatures above 40° C.
Tipping Fees	Fees charged at the point of reception for treating handling and /or disposing of waste materials.
Turning	A composting operation which mixes and agitates material in a windrow pile or vessel. Its main aeration effect is to increase the porosity of the windrow to enhance passive aeration. It can be accomplished with bucket loaders or specially designed turning machines.
Waste Diversion Potential	The capacity to divert waste material or materials from ultimate disposal by landfilling or incineration, by employing the hierarchy of Rs - Reduce, Reuse, Recycle. Incineration is a waste-to-energy plant is usually classed as Recovery, the 4th R, and is still a means of waste diversion.
Wet/Dry Collection	A 2-stream system of source separation whereby the recyclable materials are placed in one container, forming the "dry" waste stream, and other materials are put in a second container. The second, "wet" stream, is often either landfilled or further treated to remove the compostable material from the ultimate remnant which is landfilled.
Windrow	A long, relatively narrow and low pile. Windrows have a large exposed surface area that encourages passive aeration and drying.
Yard Waste	Leave, grass clipping, yard trimmings and other organic debris.